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Geochemical evolution of municipal water in the natural hydrologic system

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Geochemical evolution of municipal water in the natural hydrologic system

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Abstract

Geochemical evolution of municipal water in the natural hydrologic system

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Austin, Texas is experiencing rapid urban development, posing challenges to the resilience of water resources. Geochemical differences between stream water from relatively pristine rural vs. impacted urban watersheds in the Austin area indicate several distinct controls on stream water composition. These include differences in the composition and permeability of watershed bedrock, extent of urbanization, and the varying degrees of failure within the City of Austin's municipal water infrastructure. Significant losses of municipal water from infrastructure is common to most cities, yet little is known about the evolution of such water once it enters the natural hydrologic system, and the present study focuses on this evolution.

Austin draws municipal water from the Colorado River, which drains a terrain comprised of multiple rock types/ages having relatively high Sr isotope ratios ($^{87}Sr/^{86}Sr$), compared with those of the Cretaceous limestone bedrock and natural stream water of Austin's watersheds. This compositional distinction between municipal water/wastewater, local natural stream water, and bedrock is used as a tracer of the sources of and processes

by which seven Austin-area streams acquire their dissolved constituents. These include fluid mixing between municipal water and natural stream water, water-rock interaction (WRI) processes such as dissolution, precipitation, and recrystallization, and varying groundwater residence times.

Stream water in Waller and Shoal Creeks, Austin's most extensively urbanized watersheds, have high $^{87}Sr/^{86}Sr$ values and geochemical compositions closer to values for municipal water than to values for streams from the more rural watersheds (e.g., Onion, Barton and Bull Creeks). The compositions of stream waters from the urbanized watersheds can largely be accounted for by models of fluid mixing between natural and municipal endmembers. Additionally, the Waller and Shoal urban stream waters are less chemically evolved, with lower Sr/Ca values, than stream waters from the more rural watersheds. Waller and Shoal Creek water compositions can be accounted for by limited WRI via dissolution of these watersheds' Austin Chalk limestone bedrock. Stream water from the other watersheds can be modeled by more extensive WRI via both dissolution and recrystallization of the Glen Rose and Edwards limestone bedrock of those watersheds. The consistently limited WRI reflected in Waller Creek may be a consequence of fracture flow in the chalk, whereas more extensive WRI common to the more rural watersheds may be facilitated by higher matrix permeability and inferred longer residence time in the Glen Rose and Edwards. These results indicate that the geochemical evolution of municipal water, once transmitted into the natural system, is influenced by multiple fluid-mixing and WRI processes that reflect subtle but distinguishable differences in watershed geology. These differences also have implications for potential differences in contaminant transport in these watersheds.

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INTRODUCTION

The population of Texas is projected to double by the year 2050, with the most growth being concentrated in major cities (U.N. Dept. of Economic and Social Affairs, 2014, 2017). This will result in a boom in urbanization—particularly in central Texas, where several metropolitan cities lie. Additionally, prolonged climatic extremes are projected for the 21st century (IPCC, 2014; USGCRP, 2018). Maintaining water quality and quantity in urban watersheds will become increasingly difficult with increasing urbanization and rapid climate change, posing challenges for communities that depend on surface waters. Non-revenue water (NRW) is the difference between the volume of municipal supply water (e.g. tap water) put into to the distribution network and the volume of water charged to customers (Frauendorfer, 2010). Herein, we will refer to total municipal water as 'municipal water,' supply or drinking water as 'municipal supply,' and waste as municipal wastewater. NRW losses in Austin were around 12% in 2004 (Garcia-Fresca and Sharp, 2004) and rose to about 20% in 2019 (TWDB, 2019), which is in the typical range of 20-25% for municipal systems globally (Lerner, 1986, 2002). Understanding the municipal water contribution to the environment is important if we are to develop and use water resources in a resilient manner. We define resiliency as the ability for something to return to 'normal' or improved conditions after being altered. Geochemical differences observed between rural and urban stream waters indicate varying degrees of anthropogenic impacts from municipal supply and wastewater networks due to infrastructure failure. Previous studies have found that NRW and leaked wastewater comprises a large fraction (up to 90%) of water at some sites in urbanized streams (Christian et al., 2011; Beal et al., 2020). This study advances the understanding of the geochemical evolution of municipal water as it infiltrates the natural groundwater system and enters stream waters. Knowledge gained from this work will be important to science and society as it can be used in planning cities around watersheds to create more resilient water resources.

The urban stream syndrome

The term, "urban stream syndrome" is used to describe common effects on streams where urbanization degrades the stream ecology. Symptoms of urban stream syndrome include diminished water quality due to nutrient loading and anthropogenic pollutants, "flashy" and increased discharge during storms, and changes in stream geomorphology and stability (Paul and Meyer, 2001; Meyer et al., 2005; Walsh et al., 2005). Elevated nutrient and bacteria concentrations are ubiquitous in urban stream environments, particularly in areas where wastewater, animal waste, fertilizers, and herbicides can be transmitted to the stream through point source and nonpoint source processes (Schoonover et al., 2005). Stormflow in urban streams is characterized by a relatively rapid rise and fall of the stream hydrograph, with these events occurring more frequently and intensely than in rural streams. Stormwater pipe networks and increased impervious cover are the main drivers of this phenomenon (Dunne and Leopold, 1978; Boyd et al., 1993; Schueler, 2000; Ragab et al., 2003; Walsh et al., 2005; Shuster et al., 2007; Glick, 2009) and contribute stormwater runoff enriched in heavy metals and industrial debris to streams.

In urban areas, infrastructure leakage and irrigation with reclaimed water contribute anthropogenic pollutants to streams as point source processes (Reynolds and Barrett, 2003; Walsh et al., 2005) while storm runoff from roadways and de-icing applications applied to roads contribute as nonpoint processes. As water networks age and begin to fail, municipal supply and wastewaters leak into the subsurface and eventually discharge into a nearby stream through vadose or phreatic flow paths (Beal et al., 2020). Reclaimed water used for irrigation may also flow downgradient into nearby streams resulting in nutrient-enriched waters that promote algae blooms and disrupt natural chemical and biological processes (Porras et al., 2016). Stormflow runoff in urban areas contains high concentrations of heavy metals from vehicle debris or chemicals (i.e. brake dust, automobile fluids) and synthetic herbicides such as atrazine and cyanazine used on grass and crops in both rural and urban areas (Mahler et al., 2011; Scribner et al., 1994)

Urban stream channel morphology is characterized by a lack of woody debris (Lassettre and Kondolf, 2012), increased bank erosion and channel incision (due to frequent, high stormflow discharge), and a weak root structure in the riparian zone compared to streams in rural areas. In contrast, natural streams contain large woody debris that influence stream geomorphology (Keller and Swanson, 1979; Gregory et al., 1991) and are essential in maintaining complex habitats for aquatic species such as salmonid (Bjornn and Reiser, 1991; Fausch and Northcote, 1992). Riparian zones in urban watersheds may experience “hydrologic drought” because of a lowered water table due to increased urban channel incision (Groffman, 2003; Hardison et al., 2009). Roots in the riparian zone serve as organic matter regulators via denitrification processes in the soil and are most effective in shallow water tables (Gold et al., 2001; Kiley and Schneider, 2005). In incised urban channels with deep water tables, the riparian root system is not able to uptake organics and filter groundwater before it discharges to the stream.

Evapotranspiration by riparian vegetation can reduce the urban heat island effect (Georgi and Zafiriadis, 2006; Oliveira et al., 2011; Susca et al., 2011; Feyisa et al., 2014;

Gunawardena et al., 2017). Land disturbance (i.e. clearing of trees) of a forest canopy has been shown to increase gas exchange between the land and atmosphere and decrease moisture content (Aron et al., 2019). Urban watershed studies often focus on aquatic habitat or species degradation (Wang and Kanehl, 2003; Wang et al., 2012; Bendik et al., 2014; Gabor et al., 2018; Blanka et al., 2019), but focus less on riparian vegetation and how municipal water leakage effects this, which has implications for ecosystem resilience. A recently recognized potential impact on riparian vegetation resilience is municipal water leakage, which may buffer vegetation against water-stressed conditions during periods of drought (Burkhalter-Castro et al., 2018). Although urbanization can increase channel incision, municipal water leakage may offset the resultant lowered water table to benefit riparian vegetation (Solins and Cadenasso, 2020).

Evolution of municipal water

Studying the urban stream syndrome is an important context for understanding the effects of urbanization on watershed ecosystems. However, there are many understudied and critical controls on urban hydrology including: 1) the evolution of municipal water to the natural hydrologic system, and 2) the hydrogeologic (i.e. conduit or diffuse) flowpaths municipal water takes in the subsurface and its dependence on bedrock lithology. While the loss of water from the municipal infrastructure to the natural system is a well-established phenomenon (Larsen et al., 2003; Christian et al., 2011; Lockmiller, 2018; Lockmiller et al., 2019; Beal et al., 2020), little is known about the geochemical processes of municipal water that occur in the surface and subsurface. Understanding municipal water evolution is useful in knowing how urbanization alters stream water chemistry, and this knowledge can be applied to watershed remediation and conservation efforts. This study will investigate the evolution of municipal water by identifying and quantifying the hydrogeologic processes in an altered, urban hydrologic cycle, which has important implications for how contaminants are attenuated in the subsurface. Contaminants from anthropogenic sources such as municipal water can be reduced before reaching streams if they have spent enough time in the subsurface. Our results include published and unpublished stream and spring water analyses collected at various intervals from 2001-2020 across seven Austin-area watersheds (Fig. 1) in addition to municipal supply, wastewater, soil, and watershed bedrock samples to characterize hydrogeologic processes as a function of varying degrees of urbanization. The city of Austin sources its drinking water from the Colorado River, which drains a tributary that flows over the Llano uplift composed of Precambrian granite. This results in distinct Sr-isotope ratios between municipal water (high $^{87}Sr/^{86}Sr$) and the local Lower Cretaceous carbonate bedrock (low $^{87}Sr/^{86}Sr$) and can be used as a tool to identify municipal water leakage in natural stream waters (Christian et al., 2011; Beal et al., 2020). This study uses $^{87}Sr/^{86}Sr$ values of Austin-area stream waters to identify municipal supply and wastewater contributions across watersheds with varying degrees of urbanization. Stream water Na^+, Cl^-, F^-, NO_3^-, SO_4^{2-} concentrations are commonly used to identify anthropogenic inputs in urban streams (Rhodes et al., 2001; Nedeau et al., 2003; Clinton and Vose, 2005; Girija et al., 2006; Musgrove et al., 2010; Christian et al., 2011; Beal et al., 2020). In this study, we use these elemental concentrations of stream waters to delineate between municipal waste and supply water contributions to Austin watersheds. In addition to these analytes, K^+, Mg^{2+}, Ca^{2+}, Sr^{2+}, and HCO_3^- concentrations of stream and municipal waters are presented in a Piper diagram to further characterize municipal and natural endmembers. We define natural endmembers as stream waters from rural watersheds with low Sr-isotope ratios and low Na^{+}, Cl^{-}, F^{-}, NO_3^{-}, and SO_4^{2-} concentrations. Stream, spring, and municipal water Sr^{2+} and Ca^{2+} concentrations and the calculated partial pressure of CO_2 (P_{CO2}) and saturation indices with respect to calcite (SI_{cc}) of waters are used to identify and model dissolution and precipitation processes. Stream and spring water elemental ratios, cation and anion concentrations, and $^{87}Sr/^{86}Sr$ variations are used to understand and model the extent of fluid mixing and water-rock interaction processes (i.e. dissolution and recrystallization) in urban and rural watersheds.

Research questions and hypotheses

This study will advance the understanding of urban watershed hydro-geochemistry by addressing the following questions: 1) In urban systems with failing (i.e. leaking) municipal water infrastructure, how can we distinguish between municipal supply from wastewater contributions to the natural hydrologic cycle?; 2) What are the dominant processes by which Austin-area streams evolve?; and 3) How does municipal water evolve once it enters the natural system? Based on the results presented in this study, we propose the following hypotheses: 1) Municipal water from failed infrastructure is an important component of stream water baseflow in urbanized watersheds; 2) Stream water chemistry in Austin-area streams is controlled by differences in the local bedrock composition and extent of urbanization; and 3) Municipal water evolves by dissolution and recrystallization processes as it interacts with the underlying host rock. Each of these questions and hypotheses are relevant to addressing sustainability issues as they pertain to water resources. Information used to answer the questions posed in this study can also be used to target the sources of stream water contamination and create more resilient watersheds in urban areas.

Here we show that there is a significant failure of the municipal infrastructure in Austin, TX based on the amounts of stream water comprised of municipal water. We find a distinct control of bedrock composition on stream water composition due to dissolution processes. Watershed rock type and permeability impart a flowpath control on groundwater residence time and extent of water-rock interaction processes. This translates to geologic controls on municipal water in the natural system, and municipal supply or wastewater evolves through dissolution and recrystallization processes depending on watershed urbanization and permeability.

HYDROGEOLOGIC SETTING

Geology

In addition to municipal water contributions to the natural hydrologic cycle, the underlying bedrock can influence stream water chemistry through water-rock interaction processes. In Austin, Texas, stream waters flow over Cretaceous carbonate bedrock that is subject to dissolution and recrystallization. Within the lower Cretaceous there are compositional differences between the geologic units that comprise Austin-area watershed bedrock. These bedrock chemical differences are a result of varying marine depositional processes.

North of the Colorado River in Austin, TX, the Shoal Creek watershed is comprised of multiple major rock units (Table 1 and mapped in Figure 2). The Georgetown Formation is characterized by abundant faulting and a fine-grained to marly limestone composition. Above the Georgetown lies the Del Rio Clay—a claystone composed of montmorillonite, kaolinite, and illite—and the Buda Limestone above that, which is a soft to hard nodular, fossiliferous limestone (Young, 1977). Shoal Creek exposes the top of the South Bosque Member of the Eagle Ford Shale, which is primarily composed of calcite and montmorillonite (Young, 1977). The oldest member of the Austin Chalk, the Atco Member outcrops in the northern part of Shoal Creek and is composed of marly chalk, limestone, and small amounts of shale with clay (Young, 1977). Waller Creek flows over the Vinson Member of the Austin Chalk, which lies above the Atco, and Quaternary terrace deposits from historic flow paths of the Colorado River and its tributaries. The Atco and Vinson members are both characterized by chalky limestone, fossils, and small amounts of clay and shale, but differ in the Vinson having more chalk and thinner shale bedding (Young, 1977). We collected Austin Chalk samples at 6 locations within Shoal and Waller Creeks to determine if chalk chemical compositions vary spatially in these watersheds (Fig. 3). Overlying the Austin Chalk in some areas are terrace deposits composed of Quaternary-age red gravels and lower alluvial deposits in addition to modern Colorado River alluvium.

Bull Creek watershed geology is made up of the lower Cretaceous Trinity and Edwards Groups (Table 1). While the Glen Rose limestone is considered a low-permeability unit (Brune and Duffin, 1983; Wong et al., 2014) it has high matrix permeability (~1-100 mD; TWDB, 1972) relative to the Austin Chalk (0.03-1.27 mD; Hovorka, 1998). The Glen Rose is made up of dolomite, limestone, and marl bedding (Brune and Duffin, 1983) within the Trinity Group. The overlying Walnut Formation is medium-grained and fossiliferous, and the Comanche Peak Limestone is fine-grained, fossiliferous, and contains marl and shale within limestone bedding (Brune and Duffin, 1983). Above the Comanche Peak lies the Edwards Limestone, which is primarily comprised of fossiliferous, chert-rich dolomitic limestone characterized by abundant solution formations including dolines, caverns, and fractures. The Edwards Limestone serves as a major aquifer for central Texas and supplies drinking water to cities around Austin. The geologic units within the Bull Creek watershed reemerge south of the Colorado River in Barton, Onion, Williamson, and Slaughter Creek watersheds, and define the Edwards aquifer zones as well as supply baseflow to the creeks via abundant seeps and springs throughout the watersheds (Geismar, 2011).

Edwards aquifer zones and watershed urbanization

The Edwards aquifer is composed of the contributing, recharge, and artesian zones that primarily correspond to the Glen Rose, Edwards Limestone, and Quaternary Terrace deposits, respectively, at the surface. South of the Colorado River in Austin, Texas, these aquifer zones span from West (contributing) to East (artesian) and follow streamflow downgradient, eventually discharging into the Colorado. Barton, Onion, Williamson, and Slaughter Creek watersheds lie within the Edwards aquifer (Fig. 4) and have varying degrees of urbanization. In the present study, we use the percent impervious cover and population density as proxies for urbanization (Table 1). The watersheds analyzed in this study range from 16% to 60% impervious cover. Watersheds with high population density and extent of impervious cover that lie over the Edwards aquifer may contribute anthropogenic pollutants (via aging infrastructure) to a major water resource for central Texas. Therefore, understanding the evolution of municipal water in surface and subsurface waters is important in maintaining water quality in these watersheds.

Table 1: Urbanization and geology by watershed.

Watershed	% Impervious cover[1]	Population density[2] (persons/km^2)	Major rock units	Major soil compositions
Waller	60	2,436	Austin Chalk, Quaternary	Urban
Shoal	55	1,906	Georgetown, Del Rio, Buda, Eagle Ford, Austin Chalk, Quaternary	Urban, Tarrant
Williamson	37	1,276	Glen Rose, Edwards, Quaternary	Brackett, Speck, Tarrant
Bull	28	679	Glen Rose, Walnut, Comanche Peak, Edwards	Brackett, Tarrant
Slaughter	22	686	Glen Rose, Edwards, Quaternary	Brackett, Speck, Tarrant
Barton	16	212	Glen Rose, Edwards	Brackett, Speck, Tarrant
Onion	16	295	Glen Rose, Edwards, Quaternary	Brackett, Comfort, Lewisville

[1]Watershed Protection Dept. (2017)
[2]U.S. Census Bureau (2010)

Major soil compositions are listed in Table 1 for the watersheds studied. Watersheds that have undergone extensive urbanization are primarily composed of altered or amended soil compositions and are referred to as ‘urban’ soils (U.S. Department of Agriculture, 1974). The Speck soil is a clay loam and relatively thick layer compared to the well-drained Brackett and Tarrant soils composed of stony clay and gravelly clay loam.

Failing municipal infrastructure

As subsurface infrastructure ages, municipal pipes are more likely to fail and leak supply and wastewater into the groundwater supply, which then discharge into nearby streams. Water mains, pumps, wells, reservoirs, and septic tanks are all part of the municipal water system and are subject to failure based on material used, construction practices, pipe diameter, soil type, and infrastructure age (Shinstine, 2002). Some of these failures can result in a sizable economic loss since underground infrastructure leakage is difficult to detect until water reaches the surface. Case studies in urban areas have identified more frequent main breaks in pipes with smaller diameters, which may be due to their thin walls and lower moment of inertia, and pipes made with gray cast-iron (Kettler and Goulter, 1985; Male et al., 1990; Pelletier et al., 2003). In addition to corrosion, cast-iron pipes break primarily from manufacturing flaws, excessive forces (i.e. soil movement, faulting), and human error (Makar et al., 2000). Municipal water leaked into the subsurface will flow down the hydraulic gradient eventually discharging as a spring into streams. This transfer of municipal water to the natural system by water main leakage contributes around 5-6% of total recharge for the Barton Springs segment of the Edwards Aquifer during average recharge conditions (Passarello et al., 2012). While we are aware that previous studies have identified contributions of municipal water to surface and/or groundwaters (Rose, 2002; Huang et al., 2013; Ledesma-Ruiz et al., 2015; Shi et al., 2018), the hydrologic science community has yet to characterize the evolution of municipal water once it enters the natural hydrologic system.

METHODS & DATA SOURCES

Stream and spring waters were sampled from seven Austin-area watersheds during baseflow conditions following USGS protocol (i.e. USGS Fact Sheet 042-00) from 2001 to 2020. An antecedent dry period (no more than 0.1 inches of rainfall within 24 hours) of at least five days or a return to baseflow conditions (based on monthly average stream discharge) must occur to designate baseflow conditions. We determined the average rainfall from at least three rain gauges and stream discharge from at least two stream gauge stations in the watershed of interest using LCRA Hydromet (https://hydromet.lcra.org/). Water samples were collected in cleaned HDPE Nalgene bottles and aliquoted into acid-cleaned, 15 mL HDPE vials for cation and $^{87}Sr/^{86}Sr$ analysis and cleaned vials for anion analysis using a cleaned 0.45-micron polypropylene filter and syringe. For samples collected during this study, filters and syringes were not acid-cleaned. Filtered and unfiltered sample comparisons for cations and anions show that 58% of data are within 1% difference, and all analyses are within 6% except for one bicarbonate value at 13% difference (Table 2). This indicates that particulates in the samples do not affect the analytical results. Samples for cation and Sr isotope analyses were preserved by adding 7N HNO_3. Carbonate bedrock samples were prepared following a modified method from Montañez et al. (1996) using ammonium acetate to remove Sr from noncarbonate minerals and then dissolving the carbonates in 4% acetic acid.

Waters and bedrock collected during this study (2018-2020) were analyzed for cation concentrations and $^{87}Sr/^{86}Sr$ at the University of Texas at Austin, Department of Geological Sciences (UT DGS). Cation concentrations were measured using an Agilent 7500ce inductively coupled plasma quadrupole mass spectrometer (ICP-Q-MS) and $^{87}Sr/^{86}Sr$ values on a Thermo Scientific Triton thermal ionization mass spectrometer (TIMS). Stream and spring waters were analyzed for anion concentrations at the University of Texas at Austin, Department of Civil, Architectural, and Environmental Engineering (UT CAEE) using ion chromatography (IC) and manual titrations for alkalinity. The percent difference between anion replicate samples (n=15) are presented in Table 3. All replicate pairs are below 10% difference except for one stream water NO_3^- concentration at 12% and an F^- concentration with an anomalously high 47% difference. Detection limits for ICP-Q-MS analysis of Sr, Ca, Mg, Na, and K are 0.05, 5, 1, 3, and 2 ppb, respectively (Table 4). Detection limits for IC analysis of Cl, SO_4, and NO_3 are 0.2 ppm, and the detection limit for F is 0.04 ppm.

Field blanks (n=10) had anion and cation concentrations below the detection limits (Table 4), except for two NO_3 blanks at 5.2 ppm and one at 4.6 ppm from Waller and Onion Creek. These Waller blank nitrate values make up 64 – 98% of median stream water nitrate concentrations, while the Onion blank makes up 105% of median stream nitrate. Anion concentrations from these analyses with anomalously high nitrate field blanks are not presented in this study. Sample anion concentrations reported in Tables 9 & 10 are adjusted for analytical blanks, and approximately 11% of stream water data required these blank corrections. The EPA anion analytical method recommends a maximum holding time (difference between collection and analysis date) of 28 days for most anion analytes except for nitrate, nitrite, and phosphate, for which 48 hours is recommended (Pfaff, 1993). To investigate the potential of fluctuating anion concentrations in samples stored beyond the EPA recommended holding times, we analyzed 15 stream water replicates as aliquots from a single bottle of water collected at one site on Onion Creek and analyzed three at a time periodically over a 93-day period for Br, Cl, F, NO_2, NO_3, PO_4, and SO_4 (Table 5). These results show a 30% increase in NO_2 and NO_3, and over a 500% increase in PO_4 concentrations starting at 26 days after collection, but relatively consistent Br, Cl, F, and SO_4 values up to 93 days. We observe strong positive correlations between nitrite (R^2 = 0.61) and nitrate (R^2 = 0.88) concentrations and holding times (Fig. 5A). Sulfate concentrations are weakly, positively correlated (R^2 = 0.42) with holding times, while chloride, fluoride, and phosphate concentrations are not correlated (R^2 = 0.05 – 0.1).

Analytical uncertainty based on two times the standard error of anion sample replicates analyzed over increasing holding times (Table 5) for Cl, F, SO_4, NO_2, NO_3, and PO_4 are 3.7%, 11%, 3.2%, 17%, 54%, and 81%, respectively. Uncertainties for Cl and SO_4 values across different holding times are within 4%, which is consistent with anion replicates in Table 3.

The increase in NO_2, NO_3, and PO_4 stream water concentrations at 26 days holding time are likely caused by microbial activity and processes such as sorption and precipitation (Kotlash and Chessman, 1998; Maher and Woo, 1998), since samples for anion analyses cannot be preserved using nitric acid. Anion holding times and charge balances for samples collected during the course of this study (2018 – 2020) are presented in Table 6. We do not observe a correlation between increased holding times and charge balance error (Fig. 5B). For these samples, the optimum holding times are up to 9 days for NO_2, NO_3, and PO_4 concentrations and approximately 3 months for Br, Cl, F, and SO_4 concentrations. For cation measurements, the ICP-Q-MS average analytical uncertainty (twice the standard error of replicate internal standard analyses; Table 7) for Sr, Ca, Na, K, and Mg was 4.1%, 3.4%, 6.4%, 5.8%, and 6.0%, respectively. Replicate samples for cation concentrations have a mean difference of 4% (Table 8). Charge balances for stream, spring, and municipal water cation and anion analyses used in this study show 84% of data are within 5% of neutral, another 14% of data are within 5-10%, and all data are within 11% of neutral (Tables 9 & 10).

Samples were prepared for $^{87}Sr/^{86}Sr$ analysis following methods from Banner and Kaufmann (1994) and Musgrove and Banner (2004). Sr-isotope NBS-987 standard values averaged 0.710261 across all datasets, and plotted values shown in figures have been normalized to the mode of NBS-987 values ($^{87}Sr/^{86}Sr$ = 0.710264), whereas data presented in Tables 9 and 10 have not been adjusted for the value measured for the standard value. The analytical uncertainty for $^{87}Sr/^{86}Sr$ measurements is +/- 0.000012, based on 2-sigma of the population of NBS-987 standard analyses, and +/- 0.000019 based on average differences of sample replicates (n=6). Analytical uncertainties and NBS-987 measurements for $^{87}Sr/^{86}Sr$ values across all datasets are reported in Tables 9 and 10. Laboratory and field filtered blanks were 4-12 pg and 130 pg of Sr, respectively, which are negligible compared to the minimum analyzed Sr amount (2 µg).

This study compiles published data from Christian et al. (2011), Senison (2014), and Beal et al. (2020) in addition to data collected for the present study as labeled in Tables 9 and 10. Surface, groundwater, and municipal water data from the City of Austin (https://data.austintexas.gov), Texas Water Development Board (https://twdb.texas.gov), Musgrove and Banner (2004), Musgrove et al. (2010), and Wong et al. (2012) supplement this primary dataset. Carbonate bedrock compositions from this study, Dravis (1979), Demott (2006), Musgrove et al. (2010), Hendrix (2016), and Peavey (2017) are presented in Table 11.

Fluid mixing and water-rock interaction models are used in this study to analyze the geochemical evolution of natural and municipal waters following the methods of Banner et al. (1989), Banner and Hanson (1990), Banner et al. (1994), and Musgrove and Banner (2004). Fluid mixing between endmembers is calculated by mass balance of $^{87}Sr/^{86}Sr$ values and Sr and F^- + Cl^- concentrations. The dissolution of calcite is calculated using mass-balance to calculate Ca and Sr concentrations as dissolution progressively increases. Water-rock interaction models simulate the progressive dissolution and reprecipitation of a given mineral (i.e., calcite in the present study) and are calculated using mass-balance of $^{87}Sr/^{86}Sr$ and Sr/Ca between soil water (represented by soil leachate analyses) or municipal waters and carbonate bedrock. During each iteration, it is assumed that the water reaches equilibrium with calcite. Reaction progress for both water-rock interaction and dissolution are designated on model curves by increasing values for mmol or mg of calcite reacted per liter of water. The incongruent calcite dissolution (ICD) model accounts for trace elements (e.g. Mg and Sr) preferentially released compared to Ca (McGillen and Fairchild, 2005) during the reprecipitation of another carbonate mineral (Sinclair et al. 2012). In contrast, the model for dissolution we use does not involve reprecipitation (Banner et al. 1994). The calcite recrystallization (CR) model represents the reprecipitation of calcite from water that dissolves a fixed volume of limestone until reaching equilibrium and then is replaced by fresh water to repeat the process. Slopes for ICD and CR models are dependent on trace element partition coefficients (Sinclair et al., 2012).

Soil leachate $^{87}Sr/^{86}Sr$ data from Mauceri et al. (in prep.) and Beal et al. (2020) are used to determine: 1) the Sr composition of soil leachates that can be transported during weathering; and 2) whether soil Sr contributions to streams account for elevated $^{87}Sr/^{86}Sr$ of urbanized watershed stream water compositions. Irrigated soil $^{87}Sr/^{86}Sr$ values in semi-urbanized watersheds (<48% urbanized according to Christian et al. (2011)) span a higher range (0.7080 – 0.7092) compared to unirrigated soils (0.7078 – 0.7085) with the exception of one unirrigated Slaughter Creek sample at $^{87}Sr/^{86}Sr$ = 0.7091. In densely urbanized Shoal and Waller Creeks, some unirrigated soils have elevated $^{87}Sr/^{86}Sr$ values greater than the average $^{87}Sr/^{86}Sr$ for municipal waters (0.7091) and/or greater than municipal water and irrigated soils.

RESULTS

Municipal water in the natural hydrologic system

Stream water and endmember strontium isotope and elemental variations

We use $^{87}Sr/^{86}Sr$ values for stream samples across seven Austin-area watersheds, pipe discharge, municipal waters, and Cretaceous limestones (Fig. 6) to determine endmember and stream water Sr isotope variations across watersheds with varying degrees of urbanization. From most urbanized to rural, the watersheds are ordered as follows: Waller Creek, Shoal Creek, Williamson Creek, Bull Creek Urban (i.e. the urbanized part of Bull Creek with high road density; Fig. 4), Slaughter Creek, Bull Creek Rural (i.e. the western part of Bull Creek with low road density; Fig. 4), Barton Creek, and Onion Creek. Municipal supply water Sr isotope values range from 0.7088 – 0.7095, which is high relative to local Cretaceous limestones that span values of 0.7074 – 0.7077 (Fig. 6). Municipal wastewater has a larger range of $^{87}Sr/^{86}Sr$ from 0.7079 to 0.7090. Stream and spring waters in the most rural watersheds—Onion, Barton, and Bull Rural—maintain low Sr isotope averages similar to the $^{87}Sr/^{86}Sr$ values of the underlying Cretaceous limestone and represent a natural stream water endmember. As the degree of urbanization increases, there is an increase in the range and averages of stream water $^{87}Sr/^{86}Sr$, particularly in Bull Urban (0.7077 – 0.7087), Shoal (0.7081 – 0.7092), and Waller Creek (0.7081 – 0.7094), which range toward values for municipal supply and wastewater endmembers (Fig. 6). Pipe discharges that contribute directly to Waller Creek have a narrow range of 0.7088 – 0.7092 and elevated average relative to Waller Creek and may serve as a source of leaked municipal water.

While stream water geochemical data presented in this study spans from 2001 – 2020, we do not observe any isotopic or elemental temporal trends at any one location by year or seasonally during stream baseflow conditions. At one location on Waller Creek, data from Christian et al. (2011) and Beal et al. (2020) show fluctuating yearly Na/Cl averages in stream water samples from 2001, 2002, and 2013 (0.71, 0.62, and 0.74, respectively). Yearly Sr-isotope ratio averages at this Waller site show a slight decrease from 2001 ($^{87}Sr/^{86}Sr$ = 0.70890) to 2002 ($^{87}Sr/^{86}Sr$ = 0.70884), but this is not consistent with increasing Sr-isotope ratios observed in Bull Creek spring waters and travertine calcite from 1996 – 2007 (Demott, 2007). The lack of temporal trends in our stream water data are likely due to the high variability of municipal infrastructure failure in urbanized watersheds and absence of stream water discharge data for sample collection dates. Additionally, the sampling time period does not cover pre-urbanization (around the 1930s) of Austin-area watersheds and stream geochemical temporal trends may be better observed over several decades.

We find that municipal wastewaters are sodium-chloride type, municipal supply waters are calcium-chloride type, and stream waters are primarily calcium-bicarbonate (Fig. 7). Some Waller, Shoal, and a few Bull Urban stream waters are not calcium-bicarbonate, but rather trend towards calcium-chloride type along with municipal supply. Municipal wastewaters decouple from supply water in the cation and anion sub-triangles and have elevated $Na^+ + K^+$, Cl^-, and SO_4^{2-} concentrations compared to supply waters. While most stream waters are calcium-bicarbonate type, Waller Creek waters trend towards sodium-potassium type along with municipal wastewaters (cation sub-triangle in Fig. 7). Waller stream and spring waters also span the greatest range of Ca^{2+}, Cl^-, and SO_4^{2-} concentrations compared to other stream waters. Several Waller stream waters have Cl^- concentrations that trend towards wastewater, but two samples have concentrations greater than wastewaters (anion sub-triangle in Fig. 7). A few Waller and Shoal stream waters trend towards calcium-chloride type along with Waller Creek pipe discharges, suggesting that the input from pipe discharges may influence stream water chemistry by increasing chloride concentrations in urban watersheds. Natural stream endmembers Bull Rural and Onion Creek are distinct from densely urbanized Waller and Shoal Creek and are relatively low in $Na^+ + K^+$, Cl^-, and SO_4^{2-} concentrations. Bull Urban stream waters have intermediate concentrations that plot between the most rural (Onion) and urban (Waller) watershed data.

Municipal wastewater contains high concentrations of Na^+ and Cl^-, which have been used in previous studies as indicators of wastewater contributions to urbanized stream waters (Beal et al., 2020; Nyenje et al., 2014) in addition to determining ion exchange processes. Waller Creek stream waters span a large range of Na^+ and Cl^- concentrations along a 1:1 concentration compared to rural waters from Onion, Barton, and Bull Creek Rural (Fig. 8). These results are similar to other densely urbanized watersheds Williamson and Shoal Creek and semi-urbanized watersheds Slaughter and Bull Creek Urban. Concentrations of Na^+ and Cl^- are low in municipal supply water but are elevated in wastewaters (Fig. 8). Waller Creek pipe discharge concentrations plot between municipal supply and wastewaters and are at or below the 1:1 line. The natural stream water endmember is identified as having Na^+ and Cl^- concentrations lower than municipal supply water samples. Stream waters low in these constituents are also low in other anthropogenic tracers such as fluoride, nitrate, and sulfate (Fig. 9). As Na^+ and Cl^- increase, these anion concentrations become more variable and display a general positive correlation. Additionally, in the Onion Creek watershed, Na^+ and Cl^- increase spatially from upstream to downstream as the stream flows through the more urbanized part of the watershed including the city of Buda (Fig. 10). These results show that municipal wastewater contributions to the natural hydrologic cycle are identified in both urban and rural watersheds using Na^+ and Cl^- values.

Fluid mixing processes

In addition to using $^{87}Sr/^{86}Sr$ to identify endmembers and the total contribution of municipal water, we couple Sr isotope ratios with fluoride and chloride concentrations to delineate between municipal supply and wastewater contributions to natural stream waters (Fig. 11). Fluoride is commonly added to city tap waters for dental health and has been used as a tracer of supply main leakage in the natural environment (Christian et al. 2011; Beal et al., 2020; Lockmiller et al., 2019; Osterman, 1990). Municipal supply waters from Austin have high $^{87}Sr/^{86}Sr$ values (0.7087 – 0.7095) and a narrow range of F^- + Cl^- (along the length of mixing line I) concentrations compared to municipal wastewaters with variable $^{87}Sr/^{86}Sr$ (0.7079 – 0.7089) and F^- + Cl^- (between mixing lines I & II) concentrations. Stream waters from urbanized watersheds such as Waller, Bull Urban (Fig. 11A), Shoal, and Williamson Creek (Fig. 11B) span the range or exceed isotopic values and elemental concentrations between municipal supply and wastewater. The natural stream water endmember is comprised of low $^{87}Sr/^{86}Sr$ values and low elemental concentrations from the least urbanized watersheds Bull Rural (Fig. 11A), Onion, and Barton Creek (Fig. 11B). Calculated fluid mixing lines are plotted for natural stream water mixing with municipal supply (I) and waste (II) and account for a large portion of the creek water data. Bull Creek waters with low [Sr] have high $^{87}Sr/^{86}Sr$ values (0.7081 – 0.7085) that evolve towards high [Sr] waters with low $^{87}Sr/^{86}Sr$ (0.7077 – 0.7082) as a result of water-rock interaction (WRI) processes that decrease stream water $^{87}Sr/^{86}Sr$ to values closer to those for Cretaceous limestone, and increase Sr concentrations (Beal et al., 2020). Samples with values below fluid mixing line II are hypothesized to evolve through WRI, which is represented by dashed red arrows.

Fluid mixing models in $^{87}Sr/^{86}Sr$ versus 1/Sr concentrations space (Fig. 12) are used to assess the degree in which municipal water influences urban stream water geochemical and isotopic composition. The densely urbanized Waller Creek stream waters maintain high $^{87}Sr/^{86}Sr$ values as previously noted in Fig. 11 except for one outlier at 0.7081. Mixing lines I & II in Figure 12 illustrate fluid mixing between rural (i.e. Bull Rural) and municipal endmembers and account for most of the stream water data. Most Waller waters plot close to mixing line II with higher Sr concentrations relative to Bull low [Sr] waters and most municipal supply and wastewaters. Bull low [Sr] waters plot along or to the right of mixing line I, while Bull high [Sr] waters plot along or to the left of mixing line II. Municipal waters are variable in $^{87}Sr/^{86}Sr$ values and Sr concentrations, and span the range between high Sr Waller waters and Bull low [Sr] waters.

Geochemical modeling of water-rock interaction processes

Bedrock dissolution

To determine the dominant geochemical processes occurring in each watershed, data for water samples are compared with modeled processes of dissolution of bedrock composition by an endmember water (Figs. 12, 13). Rock compositions for dissolution models of the Austin Chalk, Glen Rose limestone, and Edwards Group dolomite are based on published and new geochemical data (Table 11). To better constrain the dissolution and recrystallization processes in the subsurface, we plot regional phreatic and vadose zone groundwater data and spring water data with the modeled dissolution of the Glen Rose limestone (Fig. 14). The Glen Rose dissolution model results have similar Sr and Ca concentration ranges to vadose drip waters from Natural Bridge Caverns in New Braunfels in central Texas (Demott, 2006), and drip waters have a lower and narrower range of Sr concentrations relative to spring and phreatic waters. Deep, phreatic groundwaters are high in Sr relative to Ca concentrations, which indicates the progressive dissolution and recrystallization of calcite.

Stream water Sr^{2+} vs. Ca^{2+} concentrations in Waller and Shoal Creeks closely correspond with the modeled dissolution of the Austin Chalk (Fig. 13A & B). Bull Creek (Fig. 13C) stream and spring waters correspond with the Glen Rose limestone dissolution lines, and unlike Waller and Shoal waters, some data have high Sr concentrations that fall to the right of these dissolution lines. The Austin Chalk has a large range of Sr concentrations compared to the Glen Rose Fm. and therefore the dissolution models for the chalk span a larger range of modeled stream water Sr^{2+}concentrations (Fig. 16). Waller stream waters exhibit a systematic trend ($R^2 = 0.86$) of Sr vs Ca concentrations (Fig. 13A & B). The Austin Chalk dissolution models that originate from municipal supply or wastewater water compositions are close approximations of the majority of Waller and Shoal Creek stream data (Fig. 13A), but they do not account for the lowest Sr^{2+} and Ca^{2+} concentrations—below 0.2 and 50 ppm, respectively. Bull Creek low [Sr] stream waters fall within the Glen Rose dissolution models, while high [Sr] and spring waters deviate from the models.

Slaughter, Williamson, Onion, and Barton Creek watersheds are south of the Colorado River and flow over the Edwards Aquifer. Here we assess the geochemical evolution of creek, spring, and groundwaters across Edwards Aquifer zones (Fig. 14). Slaughter and Williamson stream water Sr^{2+} and Ca^{2+} concentrations (Fig. 14A) fall between the Glen Rose and Edwards dissolution models, but do not exhibit a distinct trend between contributing, recharge, and artesian aquifer zones. Onion and Barton Creek stream water compositions, however, exhibit an increasing trend of Sr concentrations along the dissolution – recrystallization pathway from the contributing to recharge zone (Fig. 14B & C). While most Onion and Barton Creek stream, spring, and groundwaters in the contributing and recharge zones plot between the bedrock dissolution models, most waters in the artesian zone fall to the right of the Edwards dissolution line.

Saturation indices and PCO_2

We calculate saturation indices with respect to calcite (SI_{cc}) and the partial pressure of CO_2 (PCO_2) using Geochemist's Workbench to assess the potential for calcite dissolution versus recrystallization processes to occur in creek, spring, and municipal waters (Fig. 17). Municipal supply waters are treated by raising the pH to make waters slightly supersaturated with respect to calcite, which is consistent with our results showing increasing SI_{cc} with pH of supply waters (Fig. 17A). Stream waters, wastewaters, and pipe discharge waters also follow this positive relationship between SI_{cc} and pH but generally have lower pH values compared to supply waters. Municipal wastewaters, Waller stream waters, and Waller pipe discharge waters span the greatest range of SI_{cc} and pH values compared to Shoal, Bull, and supply waters.

In addition to other parameters such as pH and elemental concentrations, PCO_2 in waters will drive a solution to saturation or undersaturation with respect to calcite. High PCO_2 values compared to atmospheric will relatively under-saturate solutions and increase their potential to dissolve calcite, while low PCO_2 will saturate solutions and increase their potential to precipitate calcite. Since municipal supply waters are treated to become supersaturated, they have low PCO_2 values compared to untreated, undersaturated municipal wastewaters with high PCO_2 (Fig. 17B). Stream water SI_{cc} values range from 0.07 to -2 in waters with high PCO_2 concentrations and have the potential to dissolve. Some Waller Creek stream and pipe discharge PCO_2 values are as low as municipal supply water PCO_2, which may indicate an influence of supply water on Waller Creek stream water and pipe discharge water geochemistry. This may also be the case for high Waller Creek PCO_2 concentrations similar to those for municipal wastewater.

Evolution of municipal water in the natural system

WRI models and groundwater residence time

To understand how municipal water evolves in the natural system, we consider the processes that may account for the geochemical variations. In addition to modeling bedrock dissolution processes using elemental data, we model water-rock interaction (WRI) processes (i.e., recrystallization, which we define as progressive dissolution and recrystallization; Fig. 18) using $^{87}Sr/^{86}Sr$ and Sr/Ca variations in stream waters. Previously published regional phreatic and vadose groundwater chemical data from central Texas (Fig. 18A) are used as a comparison of groundwater zones to creek and spring data in Austin-area watersheds following the approach of Beal et al. (2020). These groundwaters closely follow the modeled WRI processes, with starting fluid compositions representing soil leachate values from Natural Bridge Caverns that progressively recrystallize Glen Rose Fm. limestones. Regional vadose zone groundwaters from previous studies have low Sr/Ca values and high $^{87}Sr/^{86}Sr$, closest to the soil leachate starting fluids and farthest from local Cretaceous limestone $^{87}Sr/^{86}Sr$ (Fig. 18A). The phreatic/vadose zone groundwaters and spring waters from published studies have somewhat elevated Sr/Ca and decreased $^{87}Sr/^{86}Sr$ compared to vadose waters, which have Sr isotope ratios that fall within Cretaceous limestone range due to increased interaction with the bedrock. Phreatic zone groundwaters have high Sr/Ca values and have the lowest $^{87}Sr/^{86}Sr$ values from extensive water-rock interaction. The progression from vadose to phreatic waters along the WRI lines in Fig. 18A are delineated by inferred groundwater residence time (τ) areas, following Musgrove and Banner (2010).

We compare elemental and isotopic variations for stream and spring waters and municipal water in this study to those of previously published studies to identify all possible geochemical processes that may account for the data. Bull Urban creek waters with low [Sr] have low Sr/Ca and elevated $^{87}Sr/^{86}Sr$ (0.7082 – 0.7086; Fig. 18B) compared to Bull Rural waters (0.7078 – 0.7080) and closely follow both the Glen Rose WRI pathway with soil leachate fluids (I & II)—indicating progressive dissolution and recrystallization—and dissolution model for a municipal supply starting fluid (III). Several urban spring waters fall in this short τ range along with urban creek low [Sr] waters, but these urban springs span the largest range of $^{87}Sr/^{86}Sr$ (0.7077 – 0.7087) and Sr/Ca ratios (0.0005 – 0.02 mol/L), unlike Bull Creek's rural springs, which have a relatively limited range of

$^{87}Sr/^{86}Sr$ (0.7079 – 0.0.7081) and intermediate Sr/Ca values (0.001 – 0.005 mol/L). Bull Creek stream waters with high [Sr] also have high $^{87}Sr/^{86}Sr$ (0.7078 – 0.7082) relative to rural creek waters. These urban, high [Sr] creek waters and rural waters both plot along intermediate and long τ zones (Fig. 18B). However, some high [Sr] waters plot closer to the Fluid III WRI model as opposed to Fluid I & II WRI models.

Williamson and Slaughter Creek stream waters have a high range of $^{87}Sr/^{86}Sr$ (0.7080 – 0.7087 and 0.7079 – 0.7082, respectively; Fig. 18C) and relatively low range of Sr/Ca (0.001 – 0.003 mol/L) compared to Onion and Barton Creek waters which have low-range $^{87}Sr/^{86}Sr$ (0.7079 – 0.7081) and high-range Sr/Ca (0.001 – 0.006 mol/L). The more urbanized Williamson and Slaughter Creek watershed data are within the short to intermediate τ zones along the Fluid I & II Glen Rose WRI models with one Williamson stream water that falls close to the Fluid III dissolution model. Barton and Onion Creek data are further along the Fluid I & II WRI pathways than Williamson and Slaughter Creek and plot within the intermediate to long τ zones.

The Fluid I WRI model used to interpret Waller and Shoal Creek data (Fig. 18D) is based on a Waller Creek urban soil leachate interacting with the Austin Chalk composition. Most Waller and Shoal Creek stream waters have high $^{87}Sr/^{86}Sr$ (0.7081 – 0.7093 and 0.7081 – 0.7092, respectively) and low Sr/Ca (0.001 –0.003 mol/L). Waller Creek pipe discharges generally follow the dissolution model along with most Waller Creek stream waters and several Shoal Creek waters. A few pipe discharge and Waller and Shoal creek waters plot among municipal supply and wastewaters or follow the Fluid I WRI pathway in the short or intermediate τ zones. Municipal wastewaters from the City of Austin span a relatively high range of $^{87}Sr/^{86}Sr$ (0.7079 – 0.7090) and Sr/Ca (0.002 – 0.008

mol/L) compared to creek and municipal waters. Additionally, most wastewater samples plot close to the Austin Chalk (I) and Glen Rose (II) WRI models or follow the Austin Chalk dissolution model.

To quantitatively assess processes that may govern creek and municipal waters chemical evolution, we use slopes of Incongruent Calcite Dissolution (ICD; McGillen and Fairchild, 2005) and Calcite Recrystallization (CR; Sinclair et al., 2012) models to constrain Austin watershed stream, municipal supply, and wastewater elemental ratio chemistry (Fig. 19). Bull low [Sr] waters (defined on pg. 19), a few Waller Creek pipe discharges (Fig. 19A), Onion, Slaughter, and Williamson waters (Fig. 19B) plot on or between ICD slopes I & II (I = 1.27, II = 0.73) of $\ln(Sr^{2+}/Ca^{2+})$ vs $\ln(Mg^{2+}/Ca^{2+})$ with model paths that appear to originate from municipal waters. The most urban watersheds—Waller, Shoal, and Williamson Creek (Fig. 19B)—trend towards more negative $\ln(Mg^{2+}/Ca^{2+})$ values of -1 to -3 between $\ln(Sr^{2+}/Ca^{2+})$ of 0 to 1 and appear to have steeper slopes than published ICD and CR models. Bull rural, Bull high [Sr], Onion, Barton, and one Shoal Creek water plot on or between CR slopes I & II (I = 0.85, II = 0.18) of elemental ratios. There are many Onion, Barton, Slaughter, and Williamson stream samples that plot between ICD II & CR I in addition to a municipal supply and wastewater samples (Fig. 19B).

In summary, these results show that municipal wastewater contributions to the natural hydrologic cycle can be identified in urban and rural watersheds using stream water [Cl] vs. [Na]. Stream water [F + Cl] vs. $^{87}Sr/^{86}Sr$ indicate compositions of stream waters in densely urbanized watersheds, such as Waller Creek, are influenced by municipal water. Austin-area watersheds stream water geochemistry closely corresponds to the modeled dissolution of local bedrock in addition to other processes. Waller and Shoal stream waters have a strong positive [Sr] vs [Ca] correlation and the slope of these data is distinct from the slopes of these constituents for Bull Creek stream waters. Bull Creek stream water Sr and Ca concentrations exhibit two trends; one that follows the dissolution pathway and another that follows the dissolution-recrystallization pathway. However, Waller and Shoal stream waters correspond only with the dissolution trend. The key results are used in the following section to understand stream and municipal water evolution.

DISCUSSION

The isotopic and elemental variability of Austin-area stream waters are used to identify and quantify municipal water contributions to the natural hydrologic system in urban and rural watersheds. We also use bedrock geochemistry and permeability to assess municipal water evolution. We use these key results to interpret urban hydrologic processes, including the evolution of municipal water in the natural hydrologic system and the control of small variations in bedrock composition between watersheds on stream water compositions. We integrate these results, models, and interpretations to develop a schematic model of urban hydrology in Austin-area watersheds.

Tracing municipal water in the natural environment

Natural stream water in Austin reflects the Sr isotope composition of local Cretaceous limestone while the Sr isotope composition of municipal water, derived from the Colorado River, is influenced by older Phanerozoic and Precambrian rocks of the Llano Uplift (Fig. 6). Stream waters in rural watersheds such as Onion, Barton, and parts of Bull Creek have Sr-isotope compositions similar to the watersheds' Cretaceous limestone bedrock. Higher stream water $^{87}Sr/^{86}Sr$ values that range up to values equivalent to that for municipal water in extensively urbanized watersheds such as Waller, Shoal, and Williamson Creeks are likely due to natural stream water mixing with municipal water (Fig. 11; Christian et al., 2011; Beal et al., 2020).

Using Na^+ + K^+, Cl^-, and SO_4^{2-} concentrations allows us to more accurately constrain potential municipal wastewater components in stream waters (Fig. 7). These elements are higher in wastewaters compared to supply waters. The more urbanized watershed stream waters (Waller, and Shoal) and pipe discharge contain elevated Na^+ + K^+, Cl^-, and SO_4^{2-} compared to rural watershed streams (Bull Rural and Onion). Stream water concentrations from the semi-urbanized (Bull Urban) watershed span the range between urbanized and rural stream water concentrations. Urban stream water geochemistry is distinct from semi-urbanized and rural watershed geochemistry and is strongly influenced by municipal supply and wastewater.

Almost all wastewaters trend towards higher Na^+ concentrations, and as demonstrated across all watersheds to varying extents (Fig. 8), an increase in Na^+ above the 1:1 line may indicate inputs of wastewater into streams. However, lower Na/Cl ratios are more commonly found in human and animal waste as well as municipal wastewaters (Panno et al., 2005; Townsend and Whittemore, 2005; Granato et al., 2015) due to higher chloride intake compared to sodium. Weathering of minerals can also produce elevated Na/Cl ratios. High Na^+ and Cl^- concentrations are more common in more extensively urbanized watersheds such as Bull, Waller, and Shoal Creek. An increase in Na^+ without an increase in Cl^-, or above the 1:1 line, may indicate municipal wastewater mixing with fluids that have undergone water-rock interaction processes. These processes can account for Bull Urban high [Sr] data that have elevated Na^+ concentrations, while low [Sr] data plot at or below the 1:1 line. Data below the 1:1 line may represent the dissolution of host rock and Na^+ - Ca^{2+} cation exchange with rock surfaces. Our results are consistent with the hypothesis that wastewater constituents are elevated in watersheds with a higher degree of urbanization and increased infrastructure age, such as Waller and Shoal Creeks (Christian et al., 2011). Additionally, these constituents are relatively significant in semi-urbanized watersheds such as Bull (Beal et al., 2020) and Slaughter Creeks compared to rural waters.

Stream water [F^- + Cl^-] versus $^{87}Sr/^{86}Sr$ indicate compositions of stream waters in densely urbanized watersheds, such as Waller Creek, comprise up to 90% municipal water. Nearly all this municipal water component is made up of either supply or wastewater depending on the stream waters' location between mixing curves. Several wastewater samples plot below mixing line II (Fig. 11), and the high Sr-isotope variability between wastewaters is likely due to mixing with natural groundwaters that have evolved through water-rock interaction processes. Shoal and Waller Creek stream waters and pipe discharges are primarily constrained by mixing lines I & II. One Waller sample has an elevated F^- + Cl^- concentration (460 ppm), which could be due to fluid mixing between natural water and concentrated wastewaters and/or anthropogenic contaminants (e.g. pool water). Bull, Onion, Barton, Williamson, and Slaughter Creek waters can be accounted for by fluid mixing and WRI processes (red dashed arrows in Fig. 11). While fluid mixing between natural and municipal endmembers may account for more of the urban stream waters (i.e. Shoal, Waller, Williamson), WRI accounts for variations in the rural stream waters (i.e. Onion, Barton, Bull Rural), which may be a function of both urbanization and watershed geology. The fluid mixing model results in 1/Sr concentrations versus $^{87}Sr/^{86}Sr$

space (Fig. 12) support the hypothesis that more densely urbanized watersheds (Waller and Bull Urban) have greater contributions of municipal waters compared to rural watersheds (i.e. Bull Rural). Beal et al. (2020) also uses this mixing model to infer dissolution processes occurring to the right of mixing line I (which would account for Bull low [Sr] waters) and water-rock interaction processes proceeding to the left of mixing line II (accounting for Bull high [Sr] waters). While this supports the hypothesized evolution processes in Bull Creek, it contradicts our findings that Waller Creek waters evolve primarily via dissolution processes. Using both mixing models, we find that there is a significant contribution of municipal water to the stream waters in urbanized watersheds (up to 90%), and we aim to characterize the evolution of this municipal water upon entering the natural hydrologic system.

Geologic control on stream water chemistry

Watershed stream data corresponding to the respective bedrock dissolution model reveals a subtle but distinct control of bedrock geochemistry on stream water evolution (Fig. 13). The calcite dissolution models originating from a municipal water endmember can account for the covariations of Sr^{2+} and Ca^{2+} concentrations in stream waters (Fig. 13A & C). We infer from this result that municipal water evolves via dissolution of limestone in the Waller and Shoal Creek urban watersheds (Figs. 11A and C). The few Waller Creek samples with low Sr^{2+} and Ca^{2+} concentrations may represent the natural stream water endmember in this creek that is not influenced by municipal water and that has not chemically evolved via dissolution processes (Fig. 13B). The majority of Waller and Shoal Creek stream waters closely correspond to the Austin Chalk dissolution pathways originating from municipal water and suggest limited recrystallization or chemical evolution beyond the dissolution process.

Stream waters that plot to the right of these model pathways, such as Bull Creek high Sr samples, can be accounted for by the recrystallization of calcite. The recrystallization process will preferentially discriminate against the incorporation of Sr into the recrystallized calcite, leading to an increase in the remaining solution's Sr relative to Ca^{2+} concentration., and thus driving the evolution path to the right on Fig. 13B. This process has a distinct pathway relative to the near-vertical linear trend of the limestone dissolution pathway (Fig. 13B). Bull Creek stream water exhibits dissolution and recrystallization processes, with the Bull low [Sr] group stream waters following the Glen Rose dissolution model and the high [Sr] group stream waters deviating significantly from the dissolution model (Beal et al., 2020). Shoal, Slaughter, Williamson, Onion, and Barton watersheds all show some degree of recrystallization processes. However, Waller and Shoal Creek do not exhibit this recrystallization, suggesting that Waller and Shoal stream waters are less chemically evolved than those from the other five studied watersheds. This has implications for groundwater residence times as we can infer that the decreased chemical evolution indicates less time that the water has spent interacting with the bedrock. The close correspondence between the stream water data and the model trends, as well as the distinct trends of the different model processes, have strong implications for 1) the control of small differences in limestone bedrock composition on stream water compositions, and 2) the control of watershed bedrock hydrogeology on stream water geochemical evolution processes.

Delineating aquifer zones

We use Glen Rose limestone and Edwards Group dolomite bedrock dissolution models to evaluate the potential controls of mineral-solution reaction processes and of bedrock composition on stream water variations of the contributing, recharge, and artesian zone geochemistry for stream, spring, and groundwaters flowing over the Edwards aquifer (Fig. 14). Within the contributing zone, streams incise the Glen Rose limestone and reach the Edwards Group as they flow over the recharge zone. Williamson, Slaughter, Onion, and Barton contributing-zone and recharge-zone water Sr and Ca concentrations (Fig. 14) are generally constrained by the Glen Rose and Edwards Group dissolution models, which is consistent with the Edwards Aquifer zone geology. The more urbanized watersheds, Slaughter and Williamson Creek, relative to Onion and Barton Creek, have water compositions in aquifer zones that correspond with their respective dissolution models, but do not show a shift in Ca concentrations due to recrystallization processes as they do in other watersheds (Fig. 14). However, Onion and Barton Creek water Sr and Ca data follow a trend of increasing Sr concentrations relative to Ca values that generally correspond to changing aquifer zones (Fig. 14B & C). The shift to higher Sr concentrations in Onion and Barton Creek stream waters can be accounted for by longer residence times in the artesian zone, which is supported by more chemically evolved elemental and isotopic water compositions in Fig. 18D compared to Slaughter and Williamson stream waters. These results are also consistent with Waller and Bull Creek dissolution (Fig. 13) and water-rock interaction models (Fig. 18B & D). The distribution of geochemical data in Fig. 14 can be accounted for by bedrock dissolution models that show the evolution of surface and groundwater through recrystallization processes across aquifer zones. These results indicate a strong geologic control in terms of bedrock permeability on stream water chemistry in Onion and Barton Creek watersheds.

Dissolution vs. recrystallization processes

While dissolution processes may dominate in the densely urbanized watersheds (Waller and Shoal Creek; Fig. 13A & B), the rural to semi-urbanized watershed (Barton, Onion, and Bull Creek) stream waters evolve via both dissolution and recrystallization processes (Fig. 14). To determine what drives dissolution versus recrystallization processes in urban and rural watersheds, we interpret pH and PCO_2 covariations with SI_{cc} for stream, municipal supply, and wastewaters (Fig. 17). When spring waters discharge into a stream, they typically outgas excess CO_2, which will increase SI_{cc} and in turn may drive the precipitation of calcite (Langmuir, 1971). Stream waters will trend towards equilibrium with atmospheric CO_2 ($10^{-3.4}$ atm) and continue to precipitate if supersaturated, or waters will dissolve bedrock if CO_2 is higher than atmospheric or waters are undersaturated. Mostly positive SI_{cc} values indicate that municipal waters are more likely to precipitate calcite, aside from two wastewater samples and several Waller Creek pipe discharges that have negative SI_{cc}. Average SI_{cc} for all waters are positive, suggesting precipitation as a dominant process, but experimental studies show that precipitation occurs at rates several orders of magnitude slower than dissolution processes due to the slow reaction kinetics of calcite precipitation (Buhmann and Dreybrodt, 1985; Dreybrodt et al., 1997). Watersheds that show little (Waller Creek) vs. extensive dissolution (Bull Creek) along model pathways (Fig. 13) also show SI_{cc} and PCO_2 values (Fig. 17) consistent with having undergone little dissolution (i.e. negative SI_{cc}) vs. extensive dissolution (i.e. SI_{cc} above 0). Municipal wastewater likely enters the natural system with low pH and high PCO_2 and evolves through dissolution of carbonate bedrock. While dissolution is a primary control on stream water evolution, natural stream water mixing with wastewater may account for the few undersaturated Waller Creek waters (Fig. 17A) that have not yet undergone dissolution.

Municipal water evolution and the modified hydrologic cycle

The Austin Chalk is characterized by high permeability fractures (7,100 – 286,000 mD; Stowell, 2000) and decreased matrix permeability (0.03 – 1.27 mD; Hovorka, 1998) relative to the matrix permeability of the Glen Rose limestone (~1-100 mD; TWDB, 1972). The more limited geochemical evolution of Waller Creek waters described previously (Figs. 11A & B, 17D and associated text) may be a result of fracture-flow in the Austin Chalk that decreases groundwater residence times, and the low matrix permeability of the Austin Chalk that limits matrix flow. By contrast, the greater matrix permeability and limited extent of fractures associated with the Glen Rose allows groundwaters to spend more time interacting with Glen Rose bedrock, thereby resulting in more geochemically evolved groundwaters that then discharge into streams.

To determine how chemically evolved stream waters are, we use water-rock interaction models with $^{87}Sr/^{86}Sr$ vs Sr/Ca compared with stream water data to infer relative measures of groundwater residence time (Fig. 18). Urban waters with shorter residence times may be due to municipal water dissolution of the Glen Rose limestone (Fluid III dissolution path in Fig.17 B & C) or limited WRI processes with soil leachates (Fluid I & II curves). Waters in rural and urban watersheds undergo intermediate to extensive WRI processes with the Glen Rose limestone. Stream water data from densely urbanized watersheds are accounted for by municipal water dissolution of the Austin Chalk (Fluid III in Fig. 18D) and/or WRI with urban soil leachates (Fluid I & II curves). Most urban waters follow this dissolution model and suggest it is a key geochemical process. Lower $^{87}Sr/^{86}Sr$ of some wastewaters may be due to the infiltration into the municipal waste infrastructure of subsurface fluids that evolve via dissolution and recrystallization processes.

To further constrain the geochemical evolution of stream and municipal waters, we compare water data with slopes expected for incongruent calcite dissolution, or ICD (defined on pg. 15), and calcite recrystallization, or CR (Fig. 19). Waters from both urban and rural watersheds show evidence of ICD processes. Most municipal supply and wastewaters appear to evolve via ICD. Most stream waters from densely urbanized watersheds (i.e. Waller and Shoal) cannot be accounted for by calculated ICD and CR slopes, but rather follow dissolution pathways presented in this study. Pipe discharge data plots within ICD, CR, and dissolution pathways (following Waller stream waters), and this may indicate the evolution (i.e. progressive dissolution and recrystallization of calcite) of municipal waters as they enter the natural environment. Leaked municipal waters may then enter these storm pipes that discharge into Waller Creek. Urban and rural waters exhibit recrystallization processes based on published CR slopes. There is a transition zone in geochemical space between ICD and CR models (centers of Fig. 19A &B) that may indicate both dissolution and recrystallization processes in stream and municipal waters as they spend time interacting with the bedrock.

In watersheds with low-permeability Austin Chalk, we infer that municipal or natural water spends relatively little time in the subsurface before discharging into a stream. This is based on stream water data from Shoal and Waller Creek plotted among dissolution pathways (Fig. 13) and WRI models (Fig. 18). In watersheds with relatively high-permeability Glen Rose bedrock, municipal or natural water may have short to long groundwater residence times. To better visualize the impact that geology has on groundwater flow paths, we present a conceptual diagram that integrates our observations and inferences using stream water compositions and geochemical models. The diagram outlines inferred subsurface flow paths in different geologic and urban settings (Fig. 20). The more rural watersheds, such as Barton and Onion Creek, are primarily influenced by natural water that infiltrates the subsurface, and that may take vadose or phreatic flow paths within the Glen Rose bedrock. Waller Creek, which is the most densely urbanized watershed in this study, is influenced by supply, waste, and storm pipe discharge that takes vadose flow paths based on inferred short groundwater residence times (Fig. 18D) within the low matrix permeability Austin Chalk.

IMPLICATIONS

The results of this study identify the sources of stream water dissolved constituents and addresses how leaked municipal water evolves in the natural environment leading to diminished water quality in urban watersheds. Understanding the hydrogeologic processes in an altered, urban hydrologic cycle has important implications for how contaminants are transported in the subsurface. This becomes especially important as urbanization encroaches on rural watersheds and sensitive aquifer recharge zones. We have identified that dissolution is a key geochemical process in less chemically evolved stream waters with inferred relatively short groundwater residence times. Therefore, municipal waste or supply waters spend less time being interacting with the surrounding host rock, and instead enter the stream relatively quickly with elevated $^{87}Sr/^{86}Sr$ values and concentrations of anthropogenic tracers such as SO_4^{2-}, NO_3^-, Cl^-, Na^+, and F^-. Stream waters that exhibit greater extents of geochemical evolution indicate longer groundwater residence times, and we can infer that municipal water introduced into the subsurface is more likely to be naturally filtered through water-rock interaction processes before discharging into surface waters compared with shorter residence time waters in urbanized watersheds.

Stakeholders such as taxpayers, city planners, developers, environmental groups, and local governments play important roles in preserving our watershed ecosystems to the benefit of aquatic species and the surrounding community. City planners will gain a better (i.e. more specialized and based on geochemical evidence) understanding of how anthropogenic contaminants enter streams and how they can better plan cities within watersheds depending on both watershed geology and the transfer of water from the municipal infrastructure to the natural hydrologic system. The results from this study indicate that municipal water can comprise a large portion of urban stream baseflow (up to 90%; Fig. 11) despite NRW losses at only 20% (TWDB, 2019). Knowing how and the extent to which municipal water influences stream water geochemistry may give developers and planners more motivation to design, regulate, replace, and build better subsurface infrastructure that is less likely to fail with age and prevent water main leakage that may be difficult to detect. However, it is also important to consider the unintended positive consequences of infrastructure failure, such as improving the resiliency of riparian vegetation against water-stress. As infrastructure continues to age and leak municipal water into the natural environment, one must weigh the positive versus negative consequences in order to maintain the resiliency of the whole watershed ecosystem.

CONCLUSIONS

This study has addressed a commonly overlooked part of the hydrologic cycle in urban and rural watersheds that assesses the evolution of municipal water in the natural hydrologic system. The key takeaways from this work are as follows:

1) There is significant failure of the municipal infrastructure in the Austin area based on the amounts of stream water comprised of municipal water.
2) There is a subtle but distinct control of bedrock composition on stream water chemistry due to dissolution processes.
3) Watershed geology and permeability impart a flowpath control on residence time and extent of water-rock interaction processes.

We show that based on urban and rural stream water cation, anion, and Sr-isotope compositions, there is a significant failure of the municipal infrastructure contributing supply and/or wastewater to stream waters that can be quantified using fluid mixing models (Beal et al., 2020). Up to 90% municipal water has been identified in urban stream waters, and wastewater contributions can be delineated from supply in stream waters using [F^- + Cl^-] vs $^{87}Sr/^{86}Sr$, and up to This study has identified a control of bedrock composition via dissolution processes and watershed urbanization on stream water chemistry. Small differences in Sr trace element concentrations between two lower Cretaceous marine limestones can account for the differences in stream water evolution pathways between watersheds. Geologic and permeability variations between watersheds impart a flowpath control on residence time and extent of water-rock interaction processes. The degree of urbanization also influences stream water chemistry with increased contributions of municipal supply and wastewater. In watersheds with low-permeability Austin Chalk, municipal water has relatively short groundwater residence times before discharging into the stream. In watersheds with relatively high permeability Glen Rose bedrock, municipal water may have short to long groundwater residence times.

FIGURES

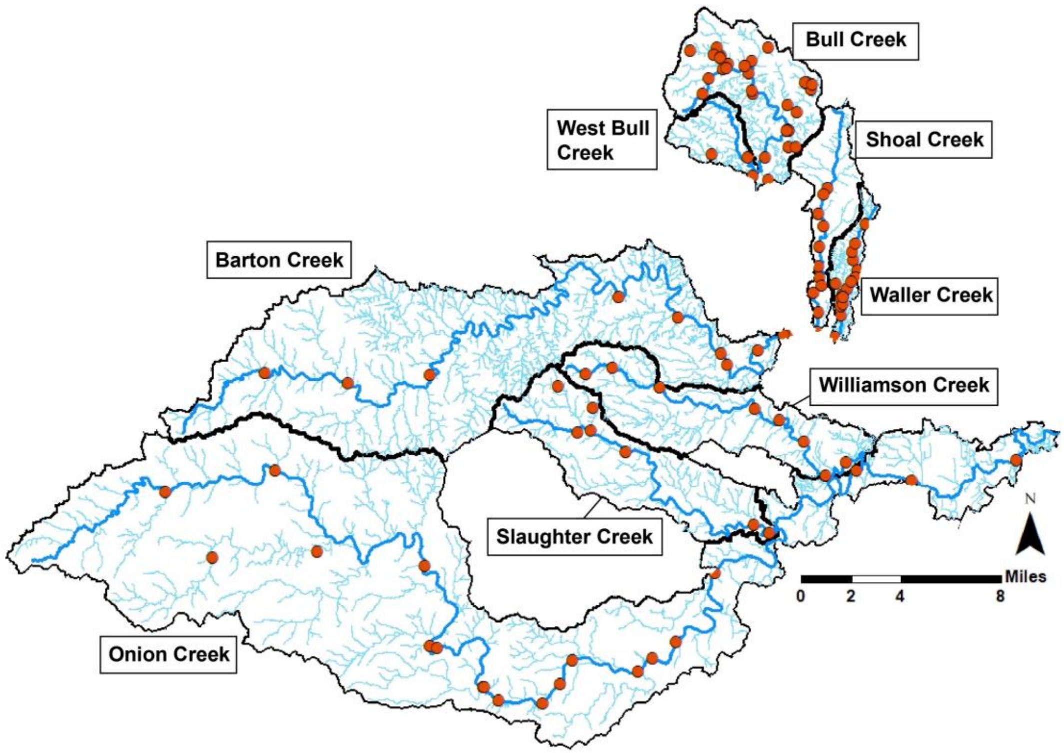


Figure 1: Sampling sites of stream and spring water samples from this study, Christian et al., (2011), and Beal et al., (2020). GIS data for streams and watershed boundaries are from the City of Austin (https://data.austintexas.gov).

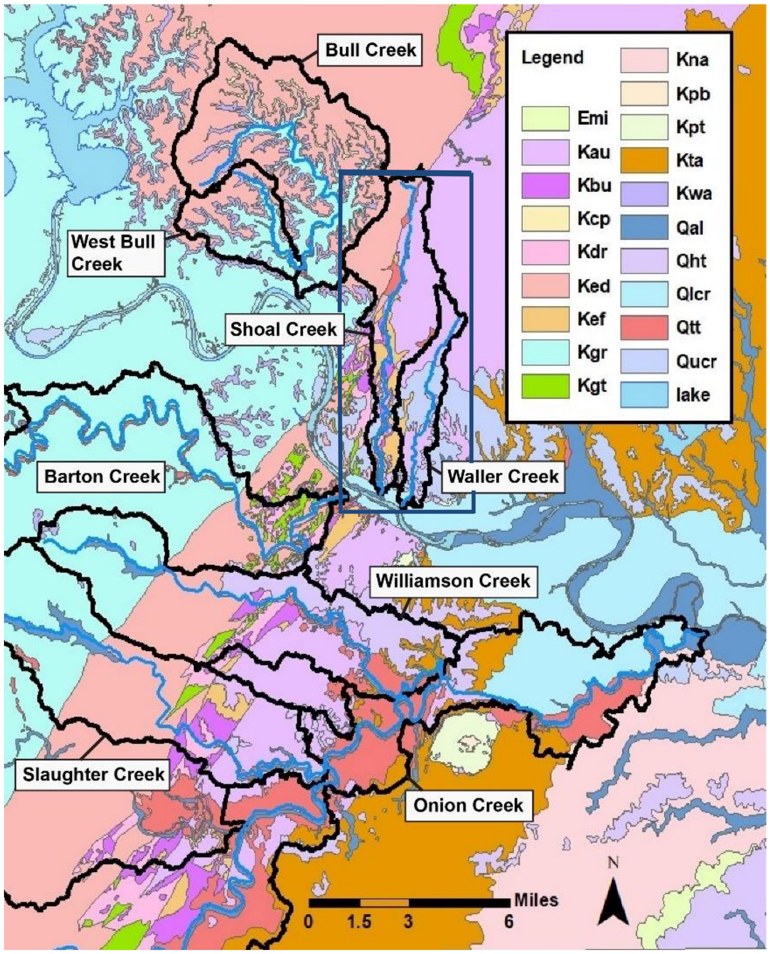


Figure 2: Geologic map of Austin-area watersheds with stream and watershed boundary GIS data from the City of Austin (https://data.austintexas.gov) and geologic data from the Bureau of Economic Geology, The University of Texas at Austin (Geology of the Austin area; 1:62,500 scale).

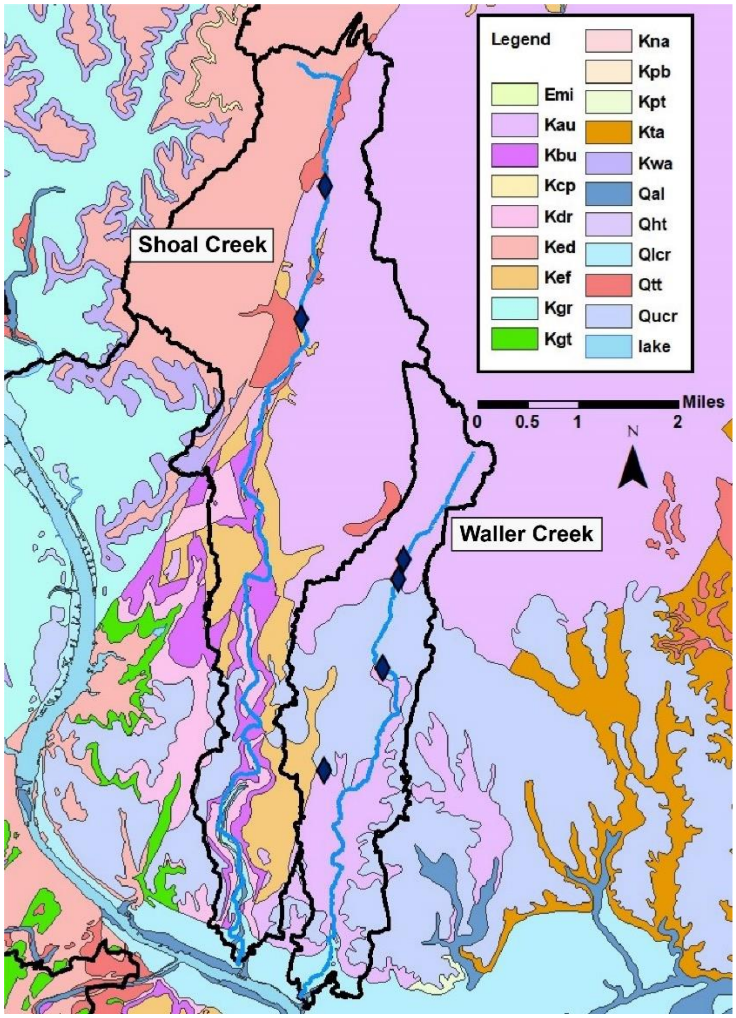


Figure 3: Geologic map of Shoal and Waller Creek (inset box in Fig. 2) showing Austin Chalk sampling sites collected during this study. Stream and watershed boundary GIS data are from the City of Austin (https://data.austintexas.gov) and geologic data are from the Bureau of Economic Geology, The University of Texas at Austin (Geology of the Austin area; 1:62,500 scale).

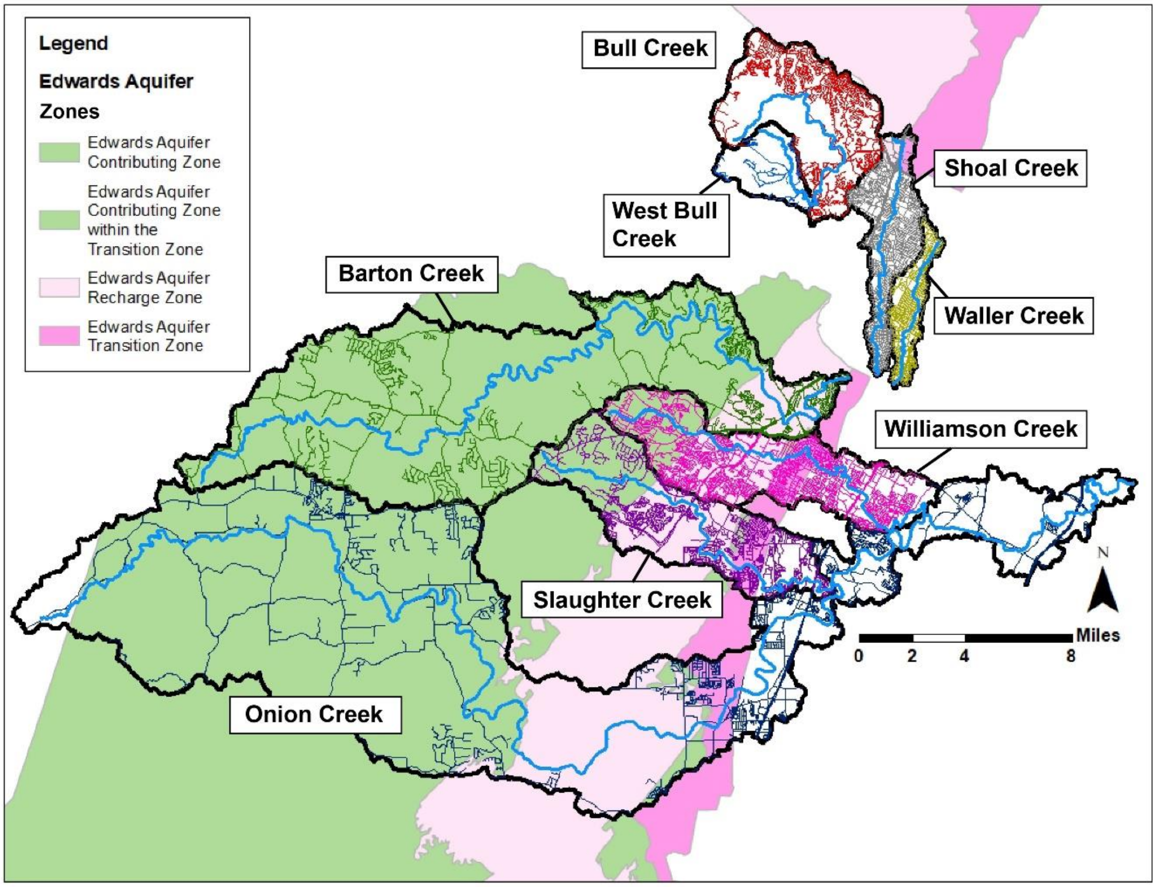


Figure 4: Map showing lines of road density and stream waters by watershed overlain by Edwards Aquifer zones. Road density, stream water, and watershed boundary GIS data is from the City of Austin and Edwards Aquifer zone boundary data is from ArcGIS public data (https://www.arcgis.com).

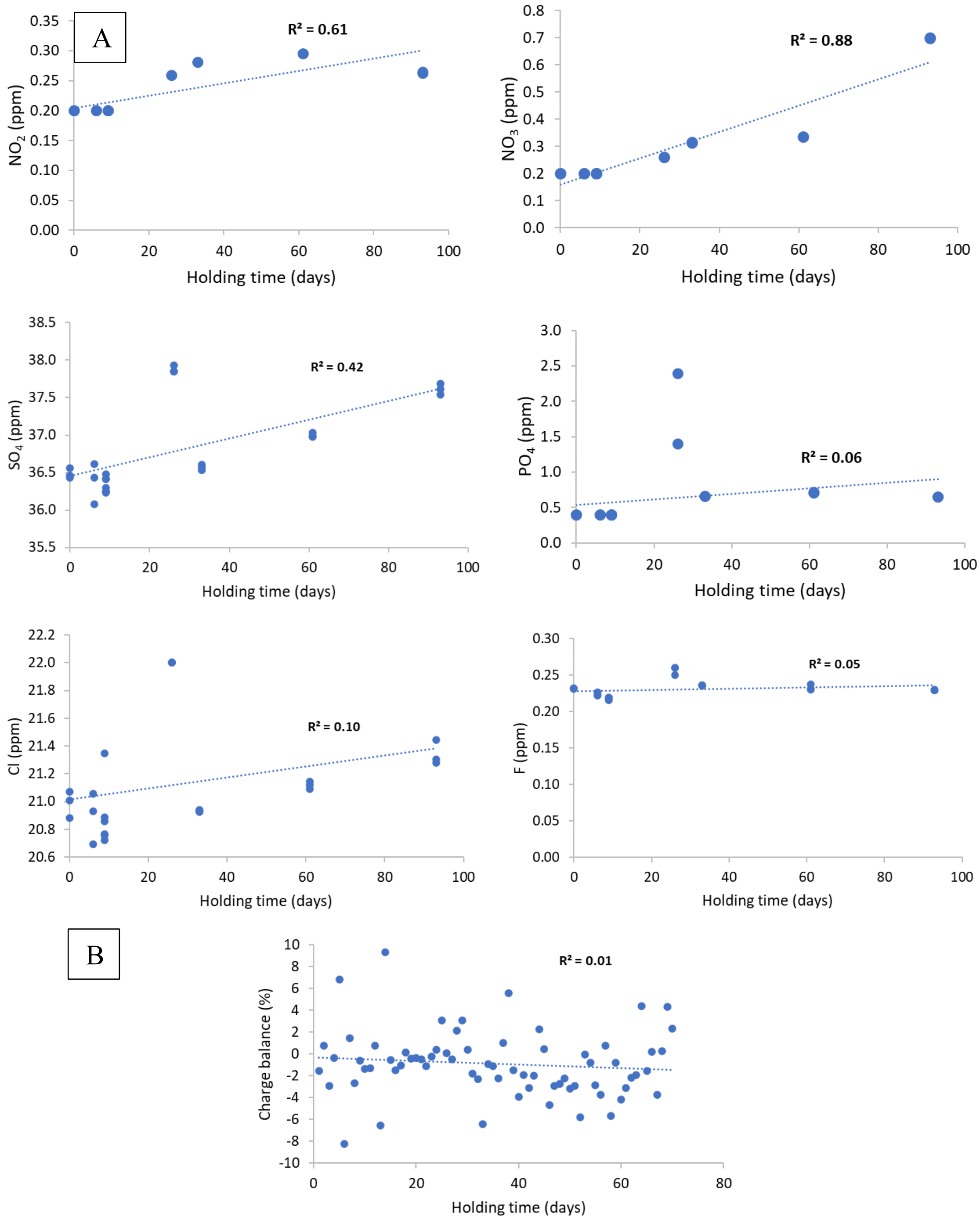


Figure 5: Anion holding times vs stream water chemistry. (A) Onion Creek anion replicate concentrations plotted against sample holding times from Table 5, and (B) stream water charge balances plotted against holding times from Table 6.

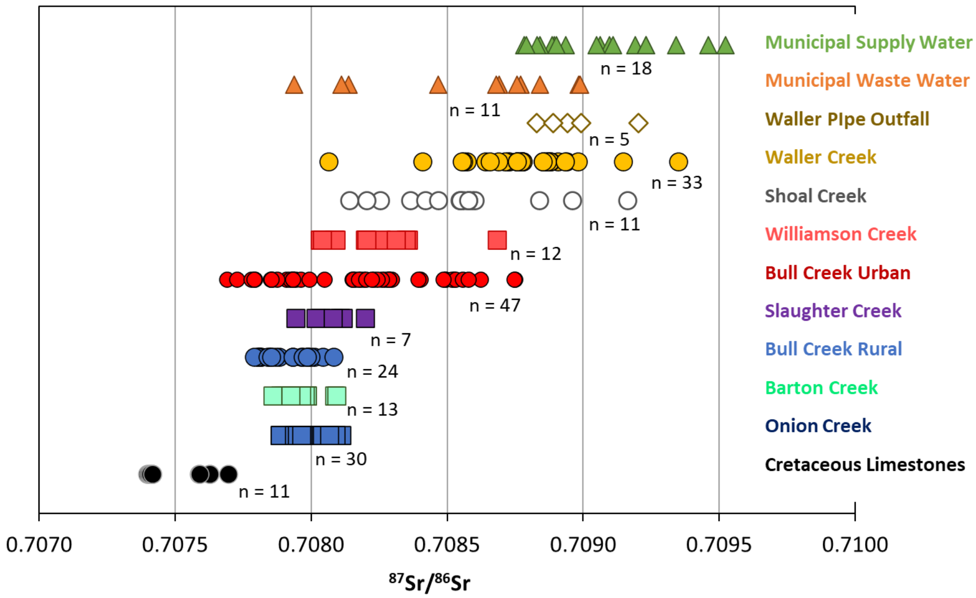


Figure 6: Distribution of $^{87}Sr/^{86}Sr$ values for municipal waters, pipe discharge (or outfall), stream waters, and Cretaceous limestones in the Austin area. All stream waters plot between two endmembers (i.e. low $^{87}Sr/^{86}Sr$ Cretaceous limestones and high $^{87}Sr/^{86}Sr$ municipal water). The analytical uncertainty for Sr isotope measurements is +/- 0.000012, which is smaller than the size of the symbols. Sr isotope averages are as follows: Municipal supply = 0.7091, municipal waste = 0.7086, Waller pipes = 0.7090, Waller = 0.7088, Shoal = 0.7085, Williamson = 0.7082, Bull Urban = 0.7082, Slaughter = 0.7081, Bull Rural = 0.7079, Barton = 0.7079, Onion = 0.7080, and Cretaceous limestones = 0.7075. Sr isotope data from this study is presented with published data from Christian et al. (2011) and Beal et al. (2020). See Tables 8 & 9 for source of each data point.

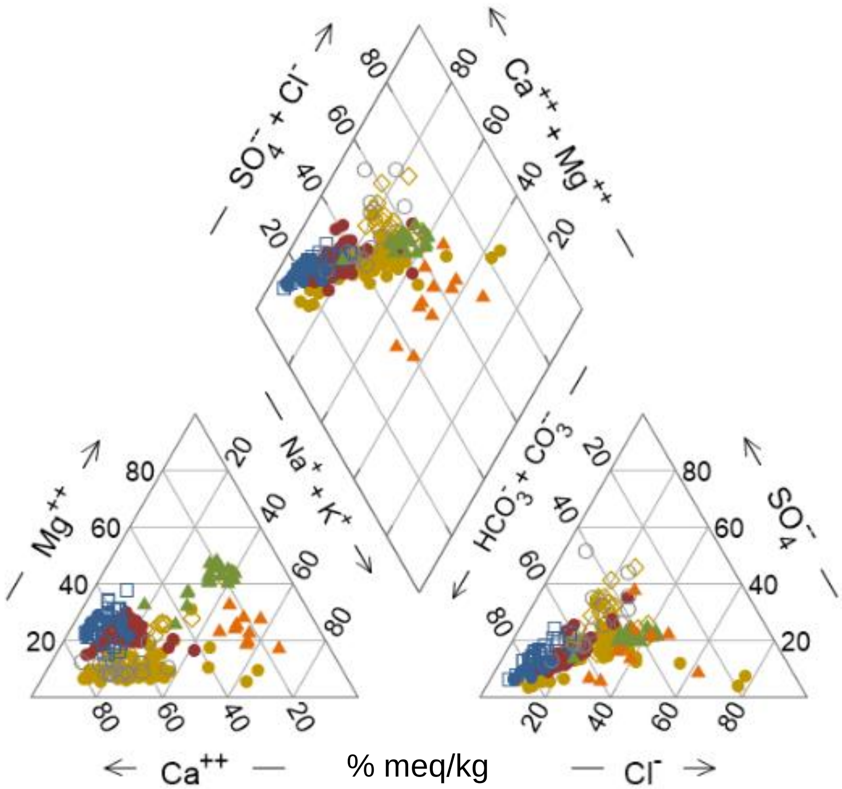


Figure 7: Piper diagram of municipal supply (green triangles), waste (orange triangles), Waller Creek stream waters (solid yellow circles), Waller Creek pipe discharge (open yellow diamonds), Shoal Creek (open grey circles), Onion Creek (open blue squares), Bull Creek Rural (solid blue circles), and Bull Creek Urban (solid red circles) Creek stream waters. Stream waters are mostly calcium bicarbonate waters, and stream waters from more urbanized watersheds have variably elevated concentrations of SO_4, Na + K, and Cl. Data from this study is combined with data from Christian et al. (2011), Beal et al. (2020), and municipal water compositions from the City of Austin.

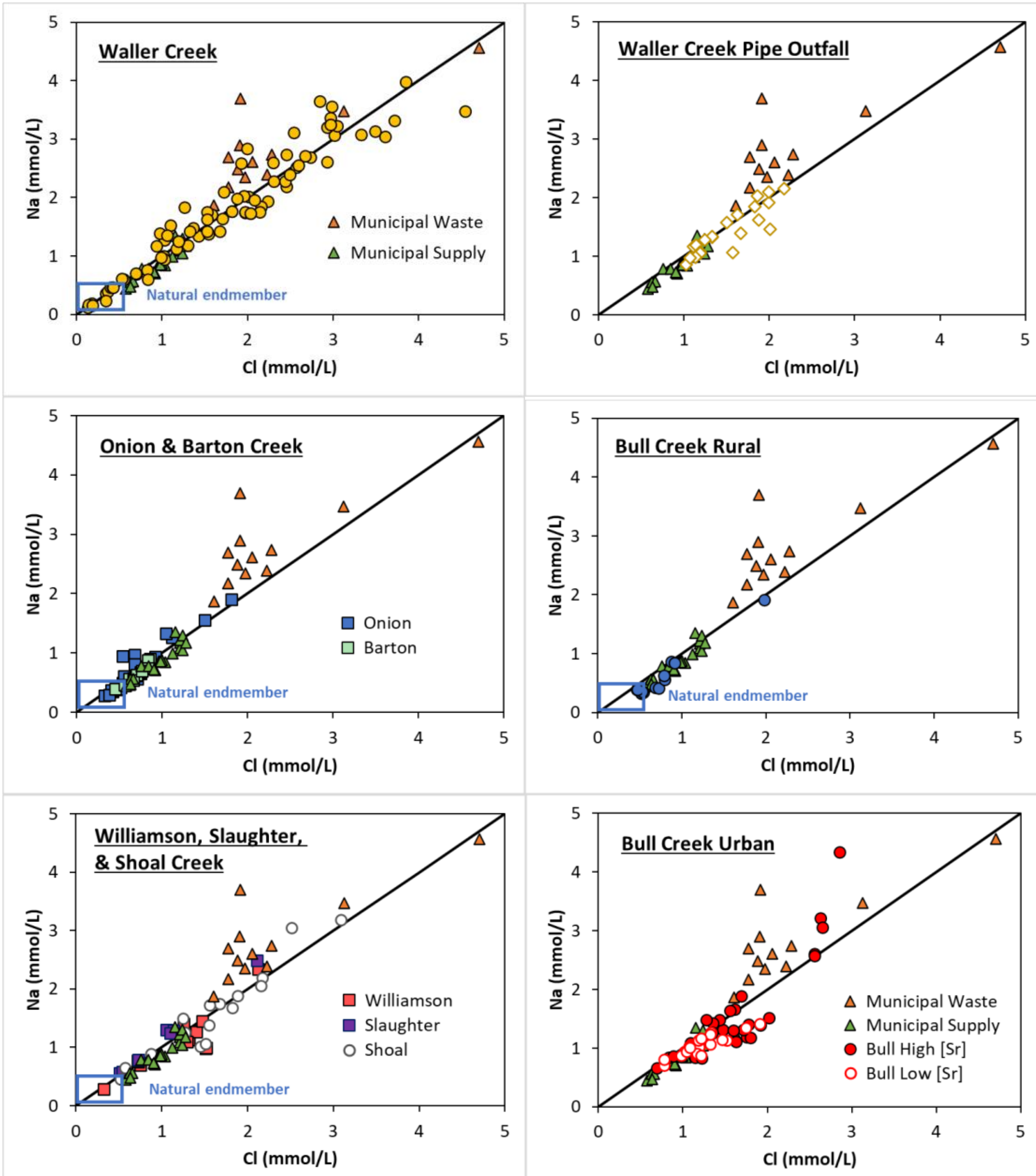


Figure 8: Chloride versus sodium concentrations up to 5 mmol/L for municipal supply, waste, pipe discharge, and stream waters for Austin-area watersheds with a 1:1 concentration line. The natural endmember outlined in a blue box is defined by low Na and Cl (i.e. less than any municipal water concentrations) and low F, NO3, and SO4 concentrations. Most stream water samples show elevated Na and Cl relative to the natural endmember, and this trend is more pronounced for the more urbanized watersheds (Waller, Bull Creek Urban, Williamson, Slaughter, and Shoal) than for the rural watersheds (Onion, Barton, and Bull Creek Rural).

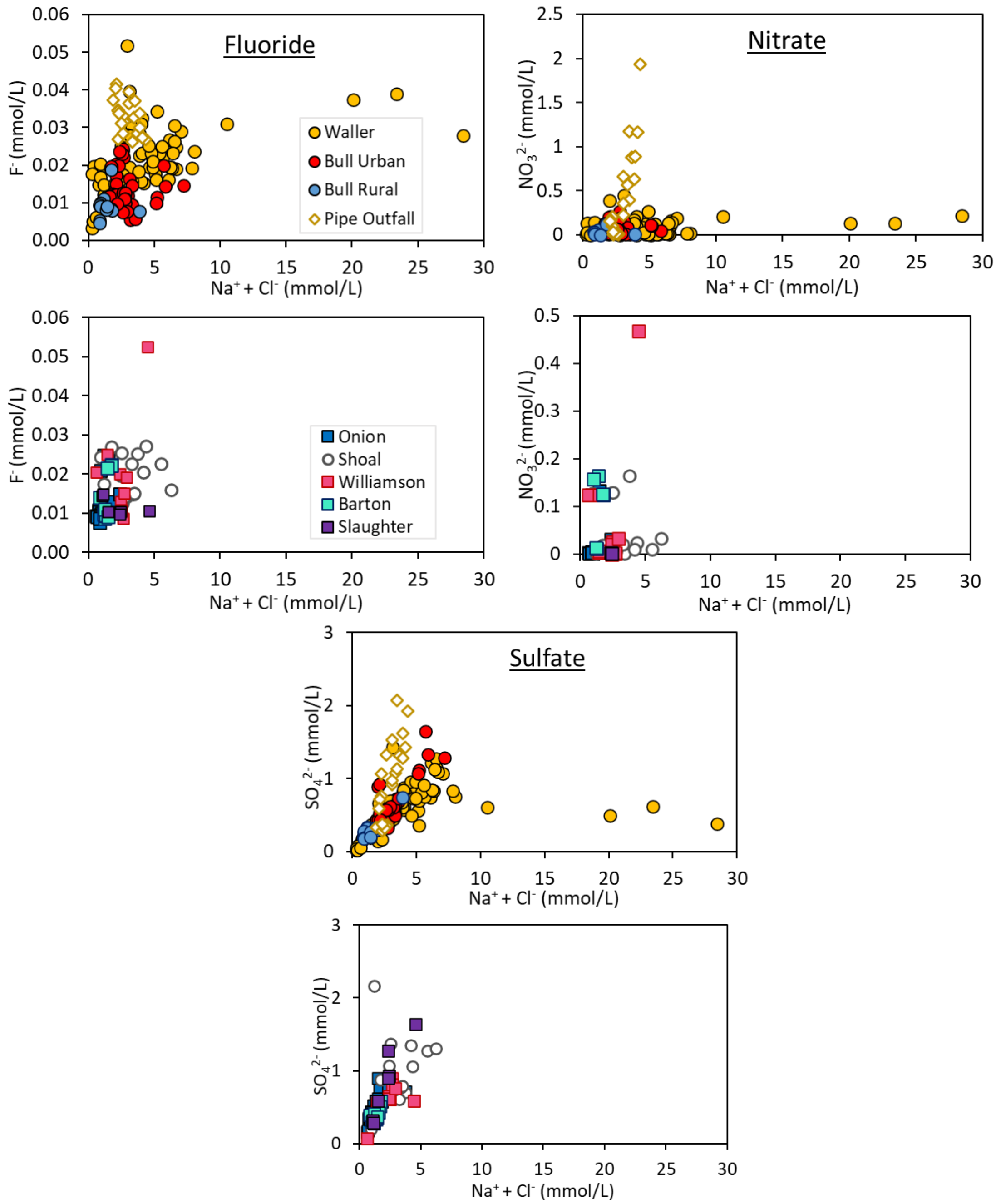


Figure 9: Select anion concentrations plotted against Na+ + Cl- of stream waters from Waller (yellow circles), Shoal (open grey circles), Williamson (pink squares), Bull Urban (red circles), Bull Rural (blue circles), Slaughter (purple squares), Barton (aqua squares), and Onion (dark blue squares) and pipe discharge from Waller Creek (open yellow diamonds).

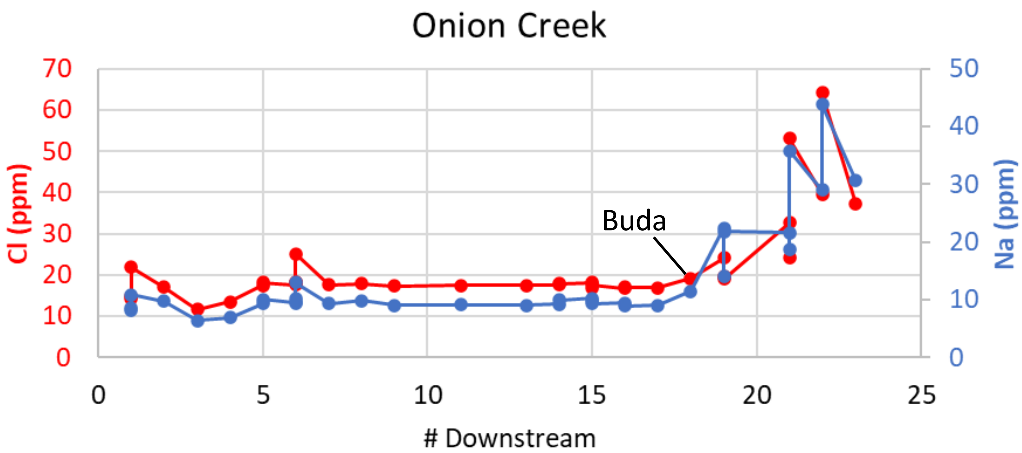
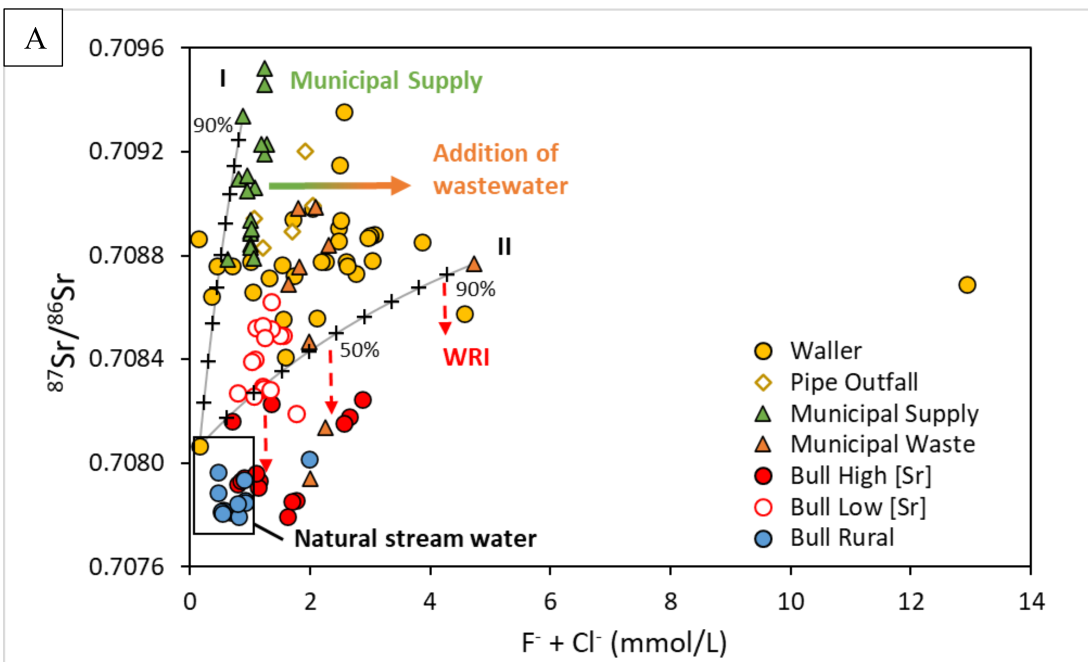


Figure 10: Spatial distribution of Onion Creek stream water Na+ and Cl- concentrations from most upstream to downstream with increasing # downstream. Buda is labeled to represent where Onion Creek flows through the city of Buda.



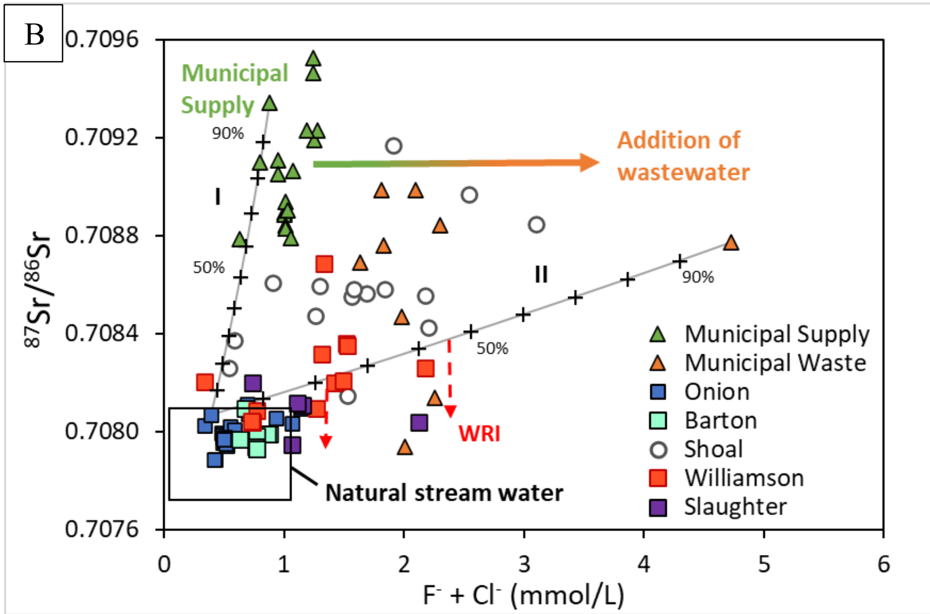


Figure 11: Fluoride and chloride concentrations versus $^{87}Sr/^{86}Sr$ for municipal supply, waste, and (A) Waller, Bull, (B) Onion, Barton, Shoal, Williamson, and Slaughter Creek stream waters. Fluid mixing line I represents mixing between a natural stream water endmember (black square) and municipal supply water with crosses at 10% increments. Fluid mixing line II represents a mixture between natural stream water and municipal wastewater. Red dashed arrows below mixing line II represent water-rock interaction (WRI) processes.

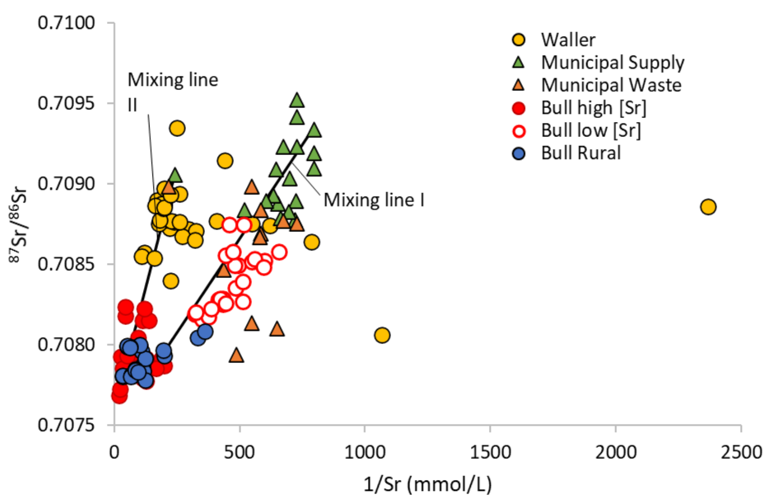


Figure 12: 1/Sr concentrations versus $^{87}Sr/^{86}Sr$ for municipal supply, waste, and stream waters from Waller and Bull watersheds. Fluid mixing lines I & II represent mixing between natural stream water endmembers (Bull Rural) and municipal supply waters.

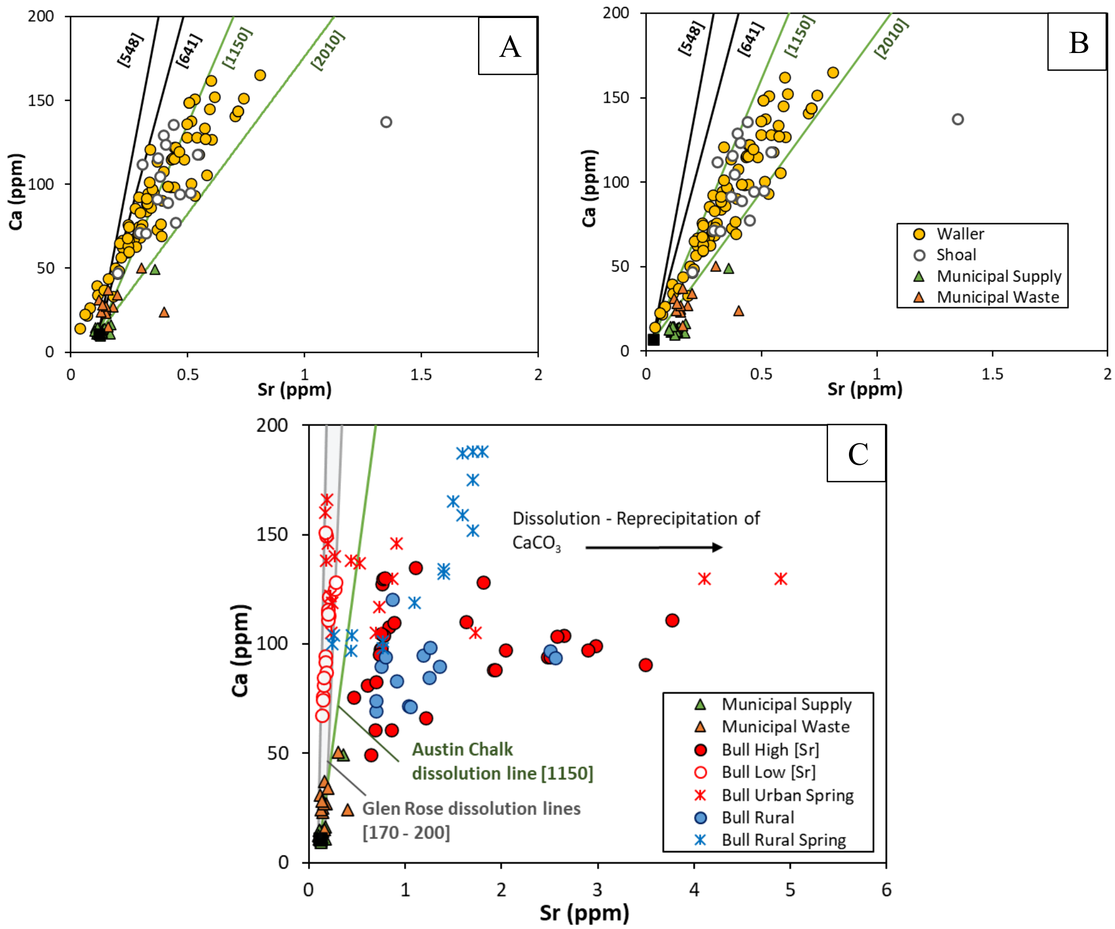


Figure 13: Sr vs Ca concentrations for stream and spring waters from Waller and Shoal Creeks (A, B). Waller Creek (yellow circles) and Bull Creek (C) with calcite dissolution models for the Austin Chalk (black and green lines) and Glen Rose limestone (grey lines) compositions and a starting fluid composition (black square) or municipal water (green and orange triangles). Numbers in brackets represent the Sr concentration of the mineral dissolved corresponding to each line. Austin Chalk dissolution lines in black use rock compositions from Waller Creek bedrock samples, and lines in green use published compositions of Austin Chalk from central Texas (Dravis, 1979). Stream, spring, and municipal water data are from this study and Christian et al. (2011) and Beal et al. (2020).

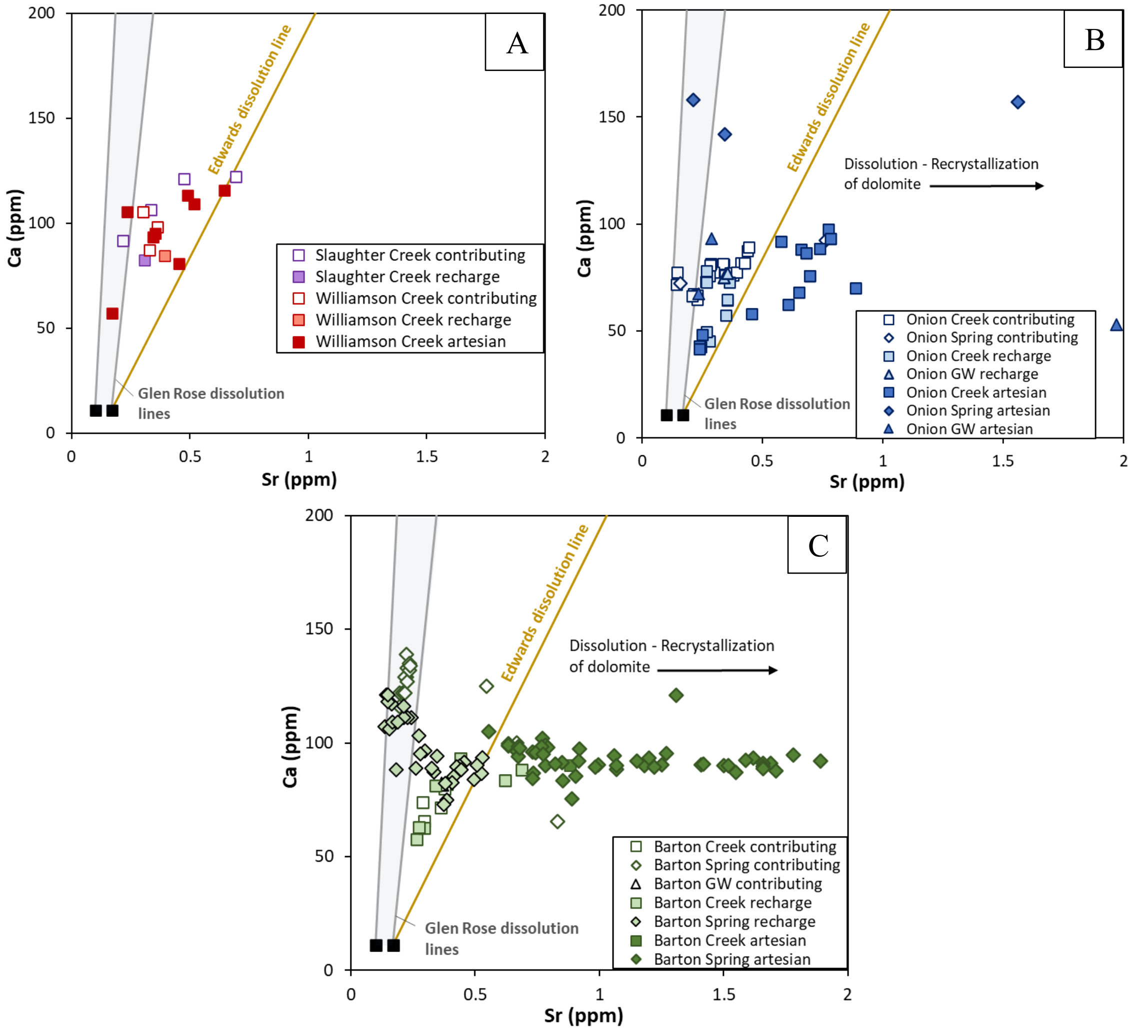


Figure 14: Groundwater, spring, and creek Ca and Sr concentrations for (A) Slaughter (purple) and Williamson (red), (B) Onion (blue), and (C) Barton (green) watersheds with distinctions of contributing, recharge, and artesian zones of the Edwards Aquifer indicated by color gradients (contributing = light, recharge = intermediate, and artesian = dark). Data collected from this study is supplemented with published data from Christian et al. (2011), Wong et al. (2012), Beal et al. (2020), Texas Groundwater Development Board (https://twdb.texas.gov), and the City of Austin (https://data.austintexas.gov). The dissolution of calcite is modeled for the Glen Rose (grey lines; Demott, 2007) and Edwards Group dolomite (yellow line; Musgrove et al., 2010) compositions interacting with starting fluids (black squares) that represent rainwater concentrations. Edwards dolomite concentrations used in this model are consistent with measured values from previous studies of the Edwards Group (Fisher and Rodda, 1969; Rose, 1972; Petta, 1977; and Ellis, 1985).

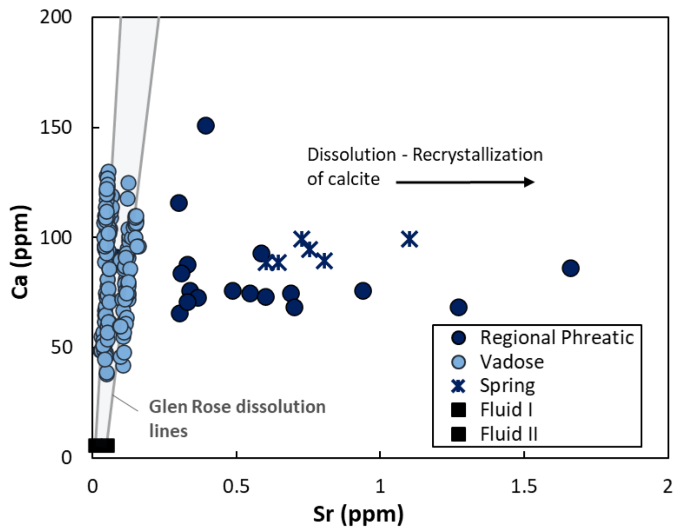


Figure 15: Regional phreatic groundwaters (dark blue circles; n=18) from central Texas and vadose drip waters (light blue circles; n=164) from Natural Bridge Caverns, San Antonio, TX (Musgrove et al., 2010; Musgrove and Banner, 2004). Spring water data (dark blue asterisks; n=6) from Barton Springs, Austin, TX (Wong et al., 2012). Glen Rose dissolution models (grey lines) use the same compositions as figures 5C & 6 from starting fluid compositions (black squares).

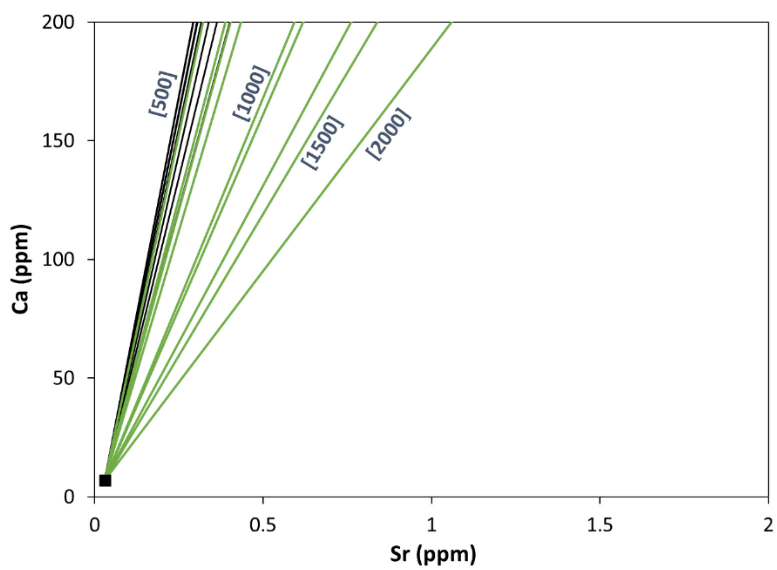


Figure 16: Austin Chalk dissolution models using published (green; Dravis, 1979; Hendrix, 2016) and unpublished (black) rock compositions interacting with a starting fluid (black square. Select rock [Sr] (ppm) are labeled next to their respective models.

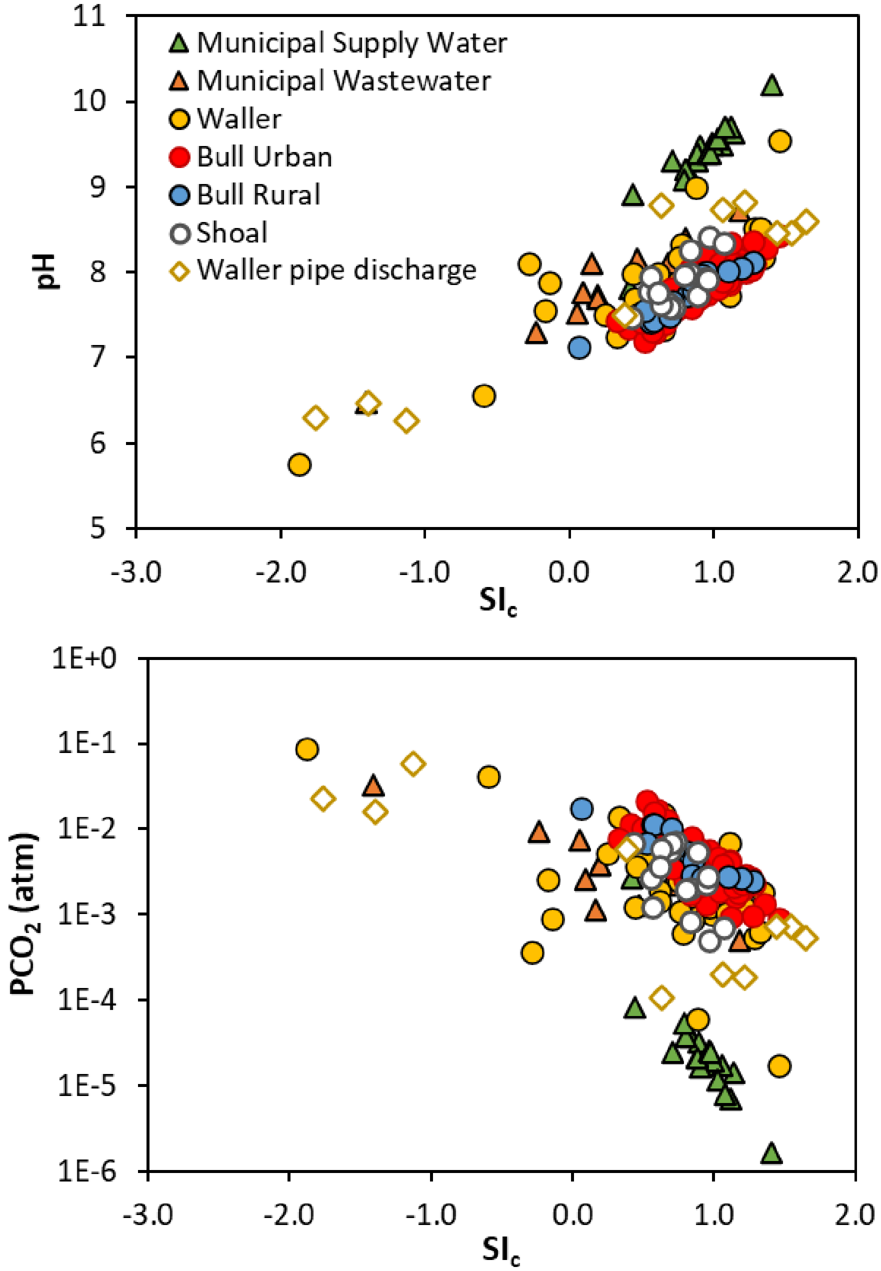
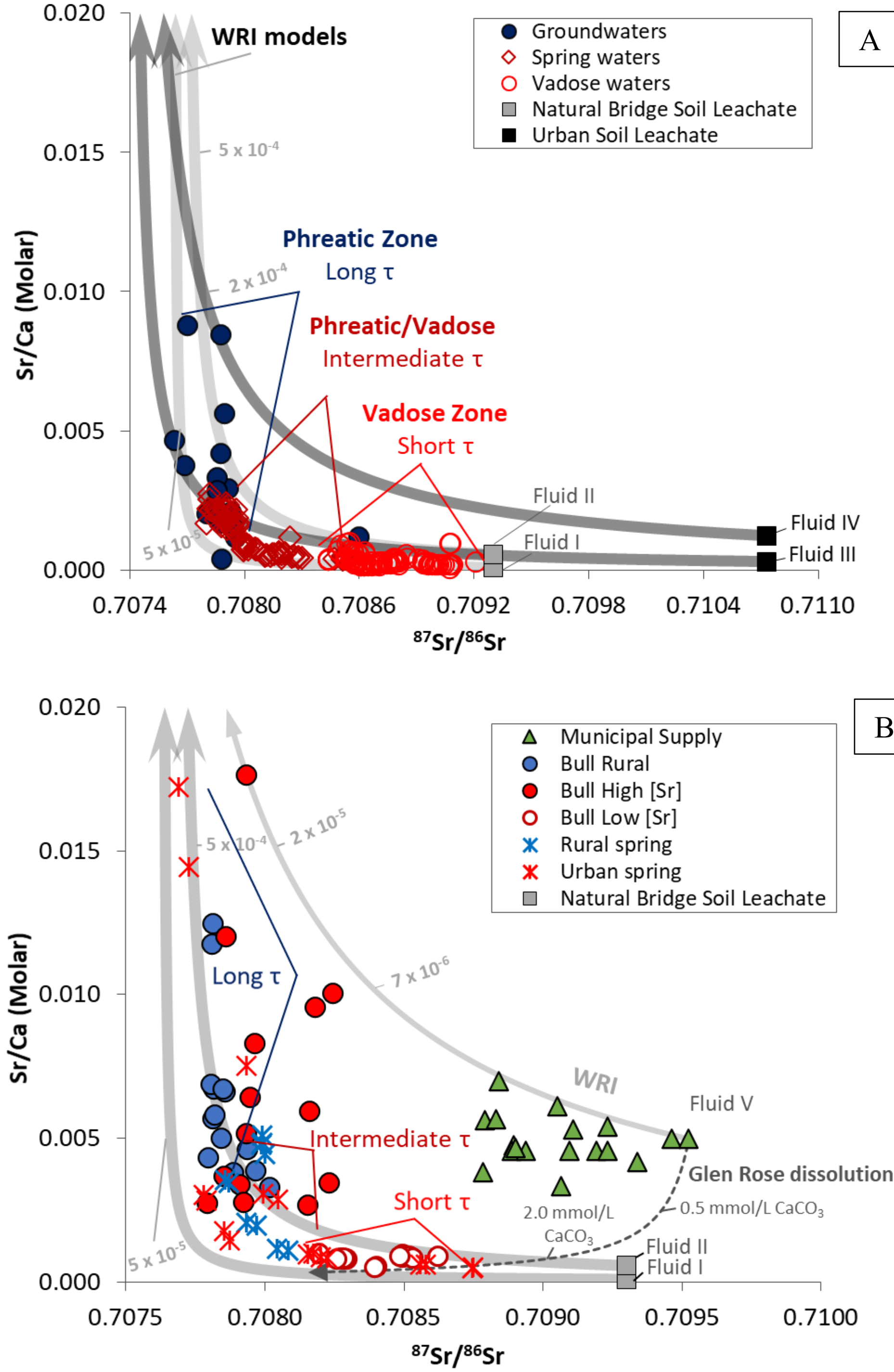
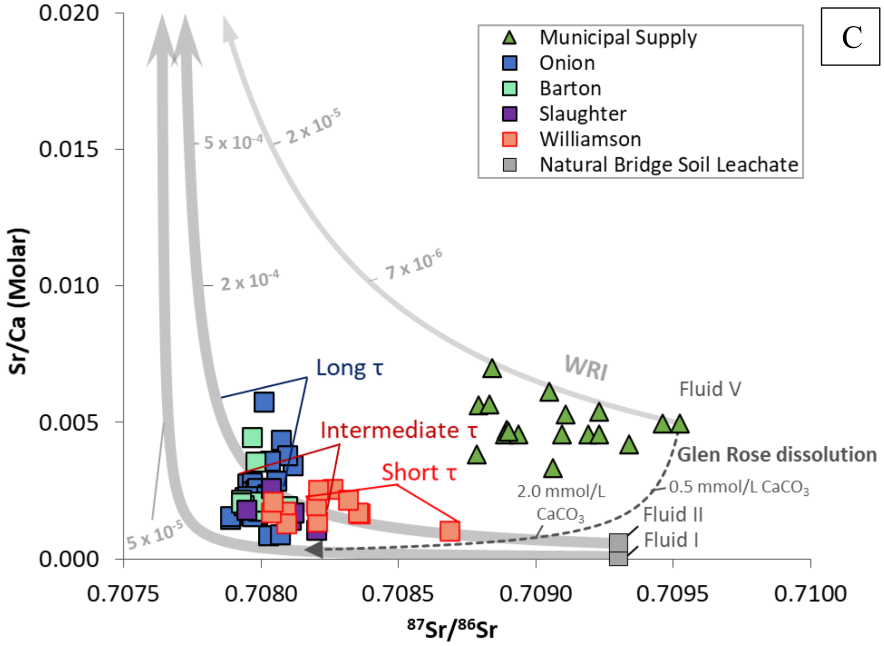


Figure 17: Saturation indices and PCO2. Saturation indices with respect to calcite versus pH (A) and the log of pCO2 (B) for stream waters from Waller, Shoal, Bull Urban, and Bull Rural watersheds as well as municipal supply and wastewater and Waller Creek pipe discharge. Water chemistry data from this study is supplemented with data from Christian et al. (2011), Beal et al. (2020), and municipal water data from the City of Austin.


A
WRI models
Groundwaters
Spring waters
Vadose waters
Natural Bridge Soil Leachate
Urban Soil Leachate
Phreatic Zone
Long τ
Phreatic/Vadose
Intermediate τ
Vadose Zone
Short τ
Fluid I
Fluid II
Fluid III
Fluid IV
Sr/Ca (Molar)
87Sr/86Sr
B
Municipal Supply
Bull Rural
Bull High [Sr]
Bull Low [Sr]
Rural spring
Urban spring
Natural Bridge Soil Leachate
Long τ
Intermediate τ
Short τ
WRI
Fluid V
Glen Rose dissolution
2.0 mmol/L CaCO3
0.5 mmol/L CaCO3
Fluid II
Fluid I
Sr/Ca (Molar)
87Sr/86Sr



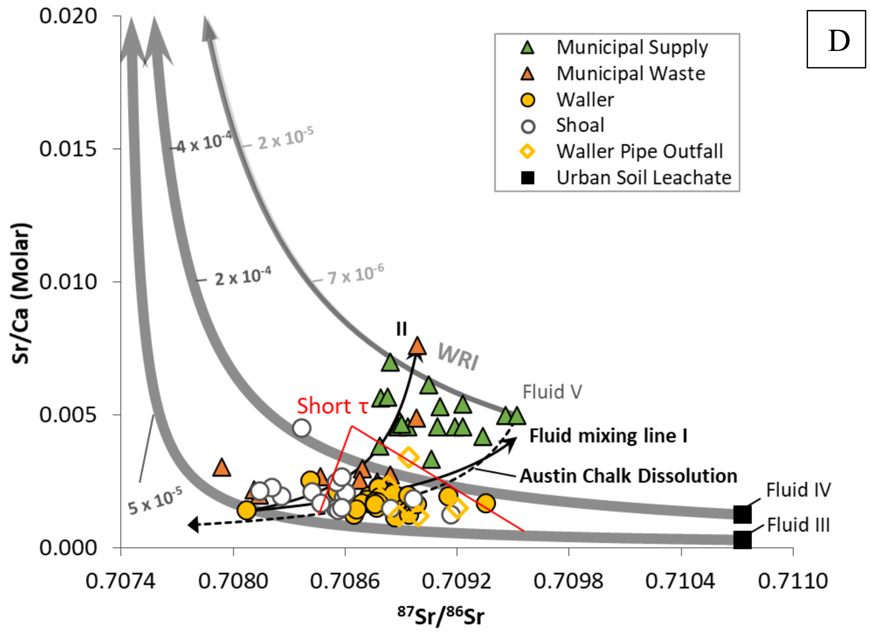


Figure 18: $^{87}Sr/^{86}Sr$ vs Sr/Ca variations for Austin-area watersheds compared with regional water compositions in central Texas: (A) regional phreatic groundwaters, vadose drip waters from Inner Space Caverns, TX (Musgrove and Banner, 2004), and spring waters from Honey Creek State Natural Area, central TX (Musgrove et al., 2010); (B) Bull Creek (modified from Beal et al., 2020); (C) Onion, Barton, Slaughter, and

Williamson Creek; and (D) Waller and Shoal Creek as well as municipal supply and wastewaters and Waller pipe discharge. Water-rock interaction (WRI; solid light and dark grey arrows) models represent the progressive dissolution and reprecipitation of the Glen Rose (A-C; Demott, 2007) and Austin Chalk (D) from a starting fluid of Natural Bridge soil leachate (Fluid I & II, A-C; Musgrove and Banner, 2004), urban soil leachate (Fluid III & IV, A & D), or municipal water (Fluid V, B – D). Dissolution of host rock (grey and dashed arrows) are modeled by iteratively adding calcite with the same Glen Rose and Austin Chalk compositions used for the WRI models. Dissolution models originate from municipal supply water (Fluid V, B – D). Molar increments are labeled along WRI and dissolution models. Groundwater residence times are represented by τ, and time designation bounds for Austin watershed stream waters are inferred based on data from (A). For (A) and (D), x-axes range from 0.7074 – 0.7110, which is different from (B) and (C) x-axes ranging from 0.7075 – 0.7100.

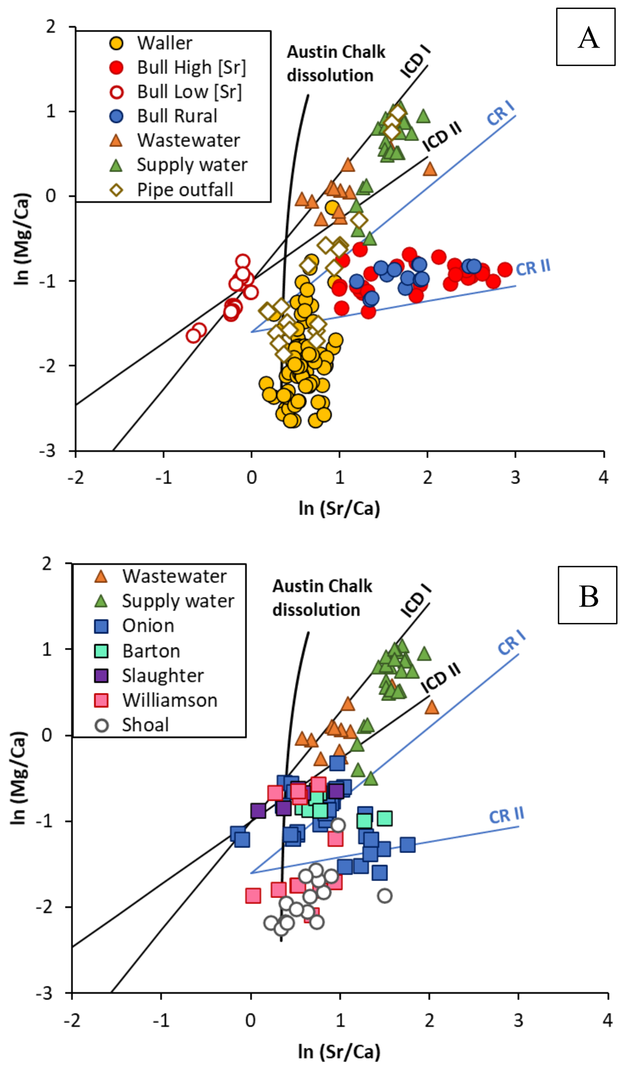


Figure 19: ln (Sr/Ca) vs ln (Mg/Ca). Stream water data from (A) Waller and Bull Creek and (B) Onion, Barton, Slaughter, Williamson, and Shoal Creek watersheds as well as municipal supply and wastewaters and Waller pipe outfalls. Incongruent calcite dissolution (ICD; black lines) slopes (ICD I = 1.27; ICD II = 0.73) are based on models from McGillen and Fairchild (2005). Calcite recrystallization (CR; blue lines) model slopes (CR I = 0.85; CR II = 0.18) are from Sinclair et al. (2012). Water data presented here is from Christian et al. (2011), Beal et al. (2020), and the City of Austin.

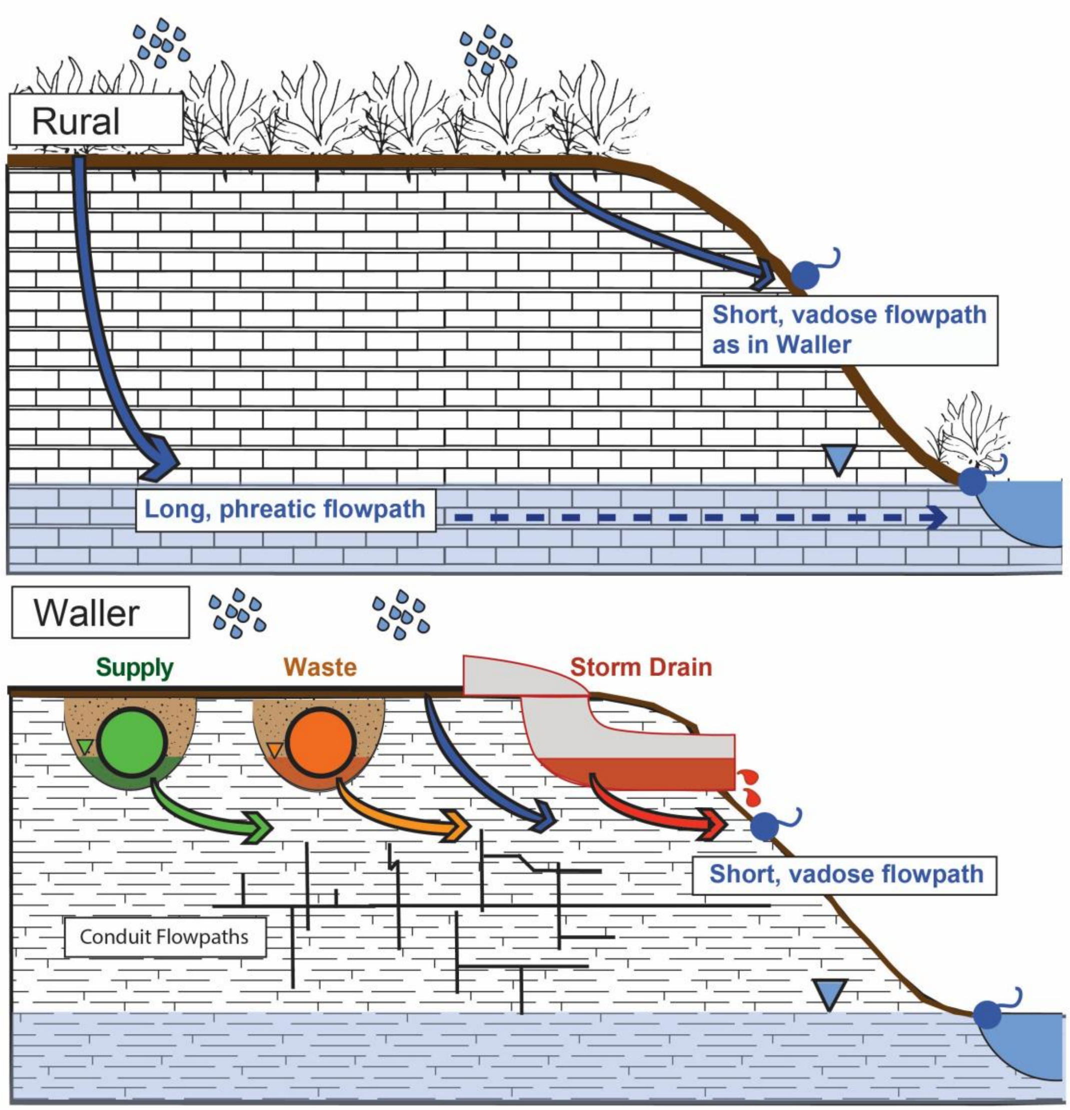


Figure 20: Cross-sectional diagrams of a rural watershed (e.g., Bull Creek) with Glen Rose limestone bedrock (top) and an urban watershed (e.g., Waller Creek) with Austin Chalk bedrock (bottom) modified from Beal et al. (2020). In the rural watershed, precipitation infiltrates a thick soil and vegetation layer and groundwater (blue arrows) either takes a shallow or deep flowpath before discharging via springs (solid blue circles). Waller Creek stream water is influenced by contributions from supply (green arrow), waste (orange arrow), storm drain outfall (red arrow), and natural waters. As indicated by a thinner blue arrow than in the rural setting, less precipitation is able to infiltrate the subsurface of Waller Creek when impervious cover is constructed on top. Municipal and natural waters spend relatively little time in the subsurface and are restricted to shallow, vadose flow through conduit flowpaths in the low-permeability Austin Chalk.

TABLES

Table 2: Filtered and unfiltered replicates.

Site Name	Filtered (µm) or Unfiltered (UF)	Sr (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	HCO3 (ppm)
WAC-1-20	0.45	0.4	91	4	19	3	268
WAC-1-20	UF	0.4	92	4	19	3	306
	% Difference	*0.1%*	*0.9%*	*0.1%*	*0.5%*	*3%*	*13%*
WAC-1	0.45	0.4	92	4	27	3	231
WAC-1	UF	0.4	92	4	27	3	229
	% Difference	*2%*	*0.6%*	*0.8%*	*0.2%*	*0.1%*	*1%*
WAC-3-20	0.45	0.2	71	3	18	3	178
WAC-3-20	UF	0.2	72	3	18	3	179
	% Difference	*1%*	*2%*	*1%*	*0.3%*	*4%*	*0.4%*
WAC-5a-20	0.45	0.3	98	13	28	13	271
WAC-5a-20	UF	0.3	99	13	28	13	260
	% Difference	*0.4%*	*0.7%*	*0.1%*	*1%*	*2%*	*4%*
WAC-5b-20	0.45	0.2	71	6	23	5	193
WAC-5b-20	0.45 rep	0.3	71	6	23	5	194
WAC-5b-20	UF	0.3	75	6	24	5	193
	% Difference	*5%*	*5%*	*4%*	*4%*	*0.1%*	*0.1%*
WAC-7	0.45	0.2	55	4	20	4	173
WAC-7	UF	0.2	59	5	21	4	174
WAC-7	UF rep	0.2	56	4	20	4	174
	% Difference	*6%*	*7%*	*6%*	*6%*	*1%*	*0.4%*

Table 3: Anion replicates for stream waters. Percent differences listed from original samples presented in Table 8.

Site Classification	Site Name	Collection Date	SO_4 (ppm)	Cl (ppm)	HCO_3 (ppm)	NO_3 (ppm)	F (ppm)
Stream Water	WAC-1-20	7/11/2018	19	14	NM	NM	0.3
Stream Water	WAC-1	7/11/2018	26	20	NM	NM	0.2
Stream Water	WAC-3-20	7/11/2018	38	30	205	NM	0.2
Stream Water	WAC-5b-20	7/11/2018	67	38	NM	NM	0.4
Stream Water	WAC-7	7/11/2018	41	32	NM	NM	0.4
Stream Water	WAC-3-20	11/29/2018	79	80	NM	10	0.3
Pipe Outfall	P40	12/5/2018	NM	NM	242	NM	NM
Stream Water	SHC-9	7/7/2019	62	45	182	8	0.5
Stream Water	WAC-1	12/19/2019	69	71	399	BDL	BDL
Stream Water	WAC-3-20	6/14/2020	85	86	282	11	BDL
Stream Water	WAC-3-20	6/14/2020	83	84	NM	11	BDL
Stream Water	WAC-3-20	6/14/2020	83	84	NM	11	BDL
Stream Water	WAC-3-20	6/14/2020	76	77	NM	10	BDL
Pipe Outfall	P40	7/17/2020	72	57	306	12	0.6
Stream Water	OC-5	7/18/2020	50	26	289	0.5	0.2

			% Difference				
Site Classification	Site Name	Collection Date	SO_4	Cl	HCO_3	NO_3	F
Stream Water	WAC-1-20	7/11/2018	9%	1%	NM	NM	9%
Stream Water	WAC-1	7/11/2018	8%	3%	NM	NM	5%
Stream Water	WAC-3-20	7/11/2018	6%	3%	1%	NM	5%
Stream Water	WAC-5b-20	7/11/2018	6%	4%	NM	NM	6%
Stream Water	WAC-7	7/11/2018	9%	7%	NM	NM	8%
Stream Water	WAC-3-20	11/29/2018	3%	5%	NM	12%	47%
Pipe Outfall	P40	12/5/2018	NM	NM	18%	NM	NM
Stream Water	SHC-9	7/7/2019	0.3%	0.3%	2%	2%	0.9%
Stream Water	WAC-1	12/19/2019	0.2%	0.1%	0.4%	BDL	BDL
Stream Water	WAC-3-20	6/14/2020	2%	2%	9%	3%	BDL
Stream Water	WAC-3-20	6/14/2020	0.1%	0.1%	NM	0.4%	BDL
Stream Water	WAC-3-20	6/14/2020	0.3%	1%	NM	0.5%	BDL
Stream Water	WAC-3-20	6/14/2020	9%	9%	NM	9%	BDL
Pipe Outfall	P40	7/17/2020	0.8%	0.7%	8%	0.2%	1.0%
Stream Water	OC-5	7/18/2020	0.5%	1%	7%	2%	0.1%

NM = not measured

BDL = below detection limits

Table 4: Field blank replicates. Cation and anion concentrations for field blank replicates from this study and instrument detection limits.

Field Blanks		ICP-Q-MS					IC			
Watershed	Collection Date	**Sr (ppm)**	**Ca (ppm)**	**Mg (ppm)**	**Na (ppm)**	**K (ppm)**	**Cl (ppm)**	**SO_4 (ppm)**	**NO_3 (ppm)**	**F (ppm)**
Waller	7/31/2018	BDL	BDL	0.005	BDL	BDL	NM	NM	NM	NM
Waller	1/28/2019	BDL	BDL	BDL	BDL	BDL	NM	NM	NM	NM
Waller	7/7/2019	BDL	BDL	BDL	BDL	BDL	NM	NM	NM	NM
Onion	12/17/2019	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Waller	12/19/2019	BDL	BDL	BDL	0.03	BDL	BDL	BDL	BDL	BDL
Waller	3/13/2020	BDL	BDL	BDL	BDL	BDL	BDL	BDL	4.6	BDL
Onion	3/13/2020	NM	NM	NM	NM	NM	BDL	BDL	5.2	BDL
Waller	4/30/2020	BDL	BDL	BDL	BDL	BDL	BDL	BDL	5.2	BDL
Waller	7/17/2020	NM	NM	NM	NM	NM	0.2	0.08	BDL	0.05
Onion	7/18/2020	NM	NM	NM	NM	NM	0.2	0.07	BDL	0.06

NM = not measured
BDL = below detection limit

Detection limits

Sr (ppb)	**Ca (ppb)**	**Mg (ppb)**	**Na (ppb)**	**K (ppb)**	**Cl (ppm)**	**SO_4 (ppm)**	**NO_3 (ppm)**	**F (ppm)**
0.05	5	1	3	2	0.2	0.2	0.2	0.04

Table 5: Anion holding time concentrations. Anion concentrations analyzed at different holding times for replicates collected at one site on Onion Creek.

Holding Time (days)	Site Name	Br (ppm)	Cl (ppm)	F (ppm)	NO2 (ppm)	NO3 (ppm)	PO4 (ppm)	SO4 (ppm)
0	OC-1 rep1	<0.20	21	0.23	<0.20	<0.20	<0.40	36
0	OC-1 rep2	<0.20	21	0.23	<0.20	<0.20	<0.40	36
0	OC-1 rep3	<0.20	21	0.23	<0.20	<0.20	<0.40	37
6	OC-1 rep4	<0.20	21	0.23	<0.20	<0.20	<0.40	37
6	OC-1 rep5	<0.20	21	0.22	<0.20	<0.20	<0.40	36
6	OC-1 rep6	<0.20	21	0.22	<0.20	<0.20	<0.40	36
9	OC-1 rep7	<0.20	21	0.22	<0.20	<0.20	<0.40	36
9	OC-1 rep8	<0.20	21	0.22	<0.20	<0.20	<0.40	36
9	OC-1 rep9	<0.20	21	0.22	<0.20	<0.20	<0.40	36
9	OC-1 rep1	<0.20	21	0.22	<0.20	<0.20	<0.40	36
9	OC-1 rep2	<0.20	21	0.22	<0.20	<0.20	<0.40	36
9	OC-1 rep3	<0.20	21	0.22	<0.20	<0.20	<0.40	36
26	OC-1 rep10	0.44	22	0.26	0.26	0.26	2.5	38
26	OC-1 rep11	<0.20	22	0.26	0.26	0.26	2.4	38
26	OC-1 rep12	<0.20	22	0.25	0.26	0.26	1.4	38
33	OC-1 rep13	<0.20	21	0.24	0.28	0.31	0.66	37
33	OC-1 rep14	<0.20	21	0.24	0.28	0.32	0.66	37
33	OC-1 rep15	<0.20	21	0.24	0.28	0.31	0.66	37
61	OC-1 rep16	<0.20	21	0.23	0.30	0.33	0.72	37
61	OC-1 rep17	<0.20	21	0.24	0.30	0.34	0.72	37
61	OC-1 rep18	<0.20	21	0.23	0.30	0.34	0.71	37
93	OC-1 rep19	<0.20	21	0.23	0.26	0.70	0.66	38
93	OC-1 rep20	<0.20	21	0.23	0.26	0.70	0.66	38
93	OC-1 rep21	<0.20	21	0.23	0.26	0.70	0.66	38

Table 6: Anion holding time charge balances.

Watershed	Site Classification	Site ID	Collection Date	Anion Analysis Date	Approx. holding time (days)	Charge Balance (% error)
Waller	Stream Water	WAC-7	9/3/2018	10/20/2018	47	-1.54
Waller	Stream Water	WAC-7	9/9/2018	10/20/2018	41	0.78
Waller	Stream Water	WAC-7	10/12/2018	10/20/2018	8	-2.93
Waller	Stream Water	WAC-7	12/19/2019	2/6/2020	49	-0.37
Waller	Stream Water	WAC-7	7/31/2018	8/13/2018	13	6.80
Waller	Stream Water	WAC-5b-20	7/11/2018	8/13/2018	33	-8.23
Waller	Stream Water	WAC-5b-20	9/3/2018	2/1/2019	151	1.44
Waller	Stream Water	WAC-5	11/29/2018	NA	NA	-2.64
Waller	Stream Water	CLASPRING	10/12/2018	2/1/2019	112	-0.64
Waller	Stream Water	WAC-3-20	7/11/2018	8/13/2018	33	-1.39
Waller	Stream Water	WAC-3-20	7/31/2018	8/13/2018	13	-1.28
Waller	Stream Water	WAC-3-20	9/3/2018	10/20/2018	47	0.73
Waller	Stream Water	WAC-3-20	9/9/2018	10/20/2018	41	-6.52
Waller	Stream Water	WAC-3-20	10/12/2018	10/20/2018	8	9.32
Waller	Stream Water	WAC-3-20	12/19/2019	2/6/2020	49	-0.55
Waller	Stream Water	WAC-3-20	11/29/2018	NA	NA	-1.52
Waller	Stream Water	DSIM	7/11/2018	8/13/2018	33	-1.05
Waller	Stream Water	DSIM	9/9/2018	10/20/2018	41	0.12
Waller	Stream Water	WAC-5b-20	10/12/2018	2/1/2019	112	-0.40
Waller	Stream Water	WAC-5b-20	12/5/2018	2/1/2019	58	-0.38
Waller	Stream Water	WAC-1-20	7/11/2018	8/13/2018	33	-0.51
Waller	Stream Water	WAC-1-20	7/31/2018	8/13/2018	13	-1.08
Waller	Stream Water	WAC-1-20	9/9/2018	10/20/2018	41	-0.25
Waller	Stream Water	WAC-1-20	12/19/2019	2/6/2020	49	0.39
Waller	Stream Water	EASTWOODS	9/9/2018	10/20/2018	41	3.04
Waller	Stream Water	EASTWOODS	7/11/2018	8/13/2018	33	0.10
Waller	Stream Water	WAC-1	7/11/2018	8/13/2018	33	-0.48
Waller	Stream Water	WAC-1	9/9/2018	10/20/2018	41	2.16
Waller	Stream Water	WAC-1	10/12/2018	10/20/2018	8	3.09
Waller	Stream Water	WAC-1	11/29/2018	NA	NA	0.39
Waller	Stream Water	WAC-1	6/27/2019	NA	NA	-1.77
Waller	Stream Water	WAC-1	12/19/2019	2/6/2020	49	-2.30
Waller	Stream Water	WAC-2	7/11/2018	8/13/2018	33	-6.44
Waller	Stream Water	USIM	7/11/2018	8/13/2018	33	-0.94
Waller	Stream Water	USRS	7/11/2018	8/13/2018	33	-1.09

Table 6 (cont.)

Watershed	Site Classification	Site ID	Collection Date	Anion Analysis Date	Approx. holding time (days)	Charge Balance (% error)
Waller	Stream Water	WAC-10	7/9/2019	NA	NA	-2.26
Waller	Pipe Outfall	P105	10/12/2018	2/1/2019	112	1.04
Waller	Pipe Outfall	P27	7/5/2018	8/13/2018	39	5.56
Waller	Pipe Outfall	P27	9/3/2018	10/20/2018	47	-1.50
Waller	Pipe Outfall	P27	10/12/2018	2/1/2019	112	-3.95
Waller	Pipe Outfall	P27	12/5/2018	2/1/2019	58	-1.91
Waller	Pipe Outfall	WAC-5a-20	7/5/2018	8/13/2018	39	-3.12
Waller	Pipe Outfall	WAC-5a-20	7/31/2018	8/13/2018	13	-1.96
Waller	Pipe Outfall	WAC-5a-20	9/3/2018	10/20/2018	47	2.28
Waller	Pipe Outfall	WAC-5a-20	10/12/2018	2/1/2019	112	0.42
Waller	Pipe Outfall	WAC-5a-20	12/5/2018	2/1/2019	58	-4.69
Onion	Stream Water	OC-1	12/17/2019	2/6/2020	51	-2.94
Onion	Stream Water	OC-15	7/7/2019	NA	NA	-2.76
Onion	Stream Water	OC-19	7/7/2019	NA	NA	-2.26
Onion	Stream Water	OC-19	12/17/2019	2/6/2020	51	-3.15
Onion	Stream Water	OC-21	7/2/2019	NA	NA	-2.94
Onion	Stream Water	OC-21	12/17/2019	2/6/2020	51	-5.83
Onion	Stream Water	OC-22	12/17/2019	2/6/2020	51	-0.06
Shoal	Stream Water	SHCK29th	7/7/2019	NA	NA	-0.82
Shoal	Stream Water	SHC-3	7/7/2019	NA	NA	-2.87
Shoal	Stream Water	SHC-9	7/7/2019	NA	NA	-3.76
Williamson	Stream Water	WIC-8	7/7/2019	NA	NA	0.75
Williamson	Stream Water	WIC-5	7/7/2019	NA	NA	-5.70
Williamson	Stream Water	WIC-2	7/7/2019	NA	NA	-0.79
Barton	Stream Water	BAC-5	7/7/2019	NA	NA	-4.15
Barton	Stream Water	BRCKGbMP	7/7/2019	NA	NA	-3.09
Barton	Stream Water	BAC-11	7/7/2019	NA	NA	-2.19
Bull	Urban Tributary	BLCKHwy360	7/3/2019	NA	NA	-1.95
Bull	Urban Tributary	BUC-4	7/3/2019	NA	NA	4.35
Bull	Rural Tributary	BUC-2	7/3/2019	NA	NA	-1.54
Onion	Stream Water	OC-6	12/17/2019	2/6/2020	51	0.19
Waller	Pipe Outfall	WAC-5a-20	12/19/2019	2/6/2020	49	-3.74
Waller	Stream Water	WAC-5b-20	12/19/2019	2/6/2020	49	0.28
Onion	Stream Water	OC-2	12/17/2019	2/6/2020	51	4.30
Onion	Stream Water	OC-5	12/17/2019	2/6/2020	51	2.33

NA = not available

Table 7: Cation analytical uncertainty. Cation concentrations for ICP-Q-MS standard replicate averages with standard deviations from NIST 1643f standard accepted values.

ICP-Q-MS					
NIST 1643f					
Accepted values	*0.031*	*2.9*	*0.73*	*1.8*	*0.19*
Analysis Date	Sr (ppm)	Ca	Mg	Na	K
2/6/2020	0.033	2.9	0.75	1.9	0.20
stdev	0.00038	0.013	0.015	0.064	0.0050
1/4/2019	0.032	2.9	0.72	1.7	0.19
stdev	0.00059	0.069	0.034	0.10	0.010
6/4/2020	0.032	3.0	0.76	1.9	0.20
stdev	0.00070	0.015	0.0090	0.020	0.0073
8/10/2019	0.031	2.8	0.72	1.9	0.19
stdev	0.00062	0.066	0.030	0.054	0.0053
7/24/2019	0.032	2.9	0.73	1.9	0.20
stdev	0.0013	0.11	0.034	0.084	0.0047
4/25/2019	0.032	2.9	0.77	1.9	0.20
stdev	0.00018	0.013	0.0092	0.031	0.0010

Table 8: Cation replicates. Stream water cation replicates and percent differences listed from original samples presented in Table 9.

Site Classification	Site Name	Collection Date	Sr (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)
Stream Water	WAC-3-20	7/11/2018	0.25	75	4	18	3
Stream Water	WAC-3-20	7/31/2018	0.37	73	6	45	3
Stream Water	WAC-1-20	9/9/2018	0.08	26	1	4	2
Stream Water	WAC-3-20	10/12/2018	0.26	80	4	20	3
Stream Water	WAC-3-20	11/29/2018	0.52	152	7	43	3
Pipe Outfall	WAC-5a-20	12/5/2018	0.33	100	13	38	10
Stream Water	WAC-1-20	1/28/2019	0.53	118	5	26	2
Stream Water	SHC-9	7/7/2019	0.36	85	6	34	3
Stream Water	OC-19	12/17/2019	0.71	76	11	22	3
Stream Water	WAC-1	12/19/2019	0.72	146	7	41	2
Stream Water	WAC-3-20	3/13/2020	0.45	124	6	40	3

			% Difference				
Site Classification	**Site Name**	**Collection Date**	**Sr**	**Ca**	**Mg**	**Na**	**K**
Stream Water	WAC-3-20	7/11/2018	1%	0.2%	2%	1%	2%
Stream Water	WAC-3-20	7/31/2018	2%	2%	1%	1%	10%
Stream Water	WAC-1-20	9/9/2018	0.1%	0.1%	1%	0.03%	0.4%
Stream Water	WAC-3-20	10/12/2018	6%	7%	8%	9%	0.1%
Stream Water	WAC-3-20	11/29/2018	2%	1%	5%	7%	3%
Pipe Outfall	WAC-5a-20	12/5/2018	2%	2%	5%	6%	4%
Stream Water	WAC-1-20	1/28/2019	4%	3%	1%	2%	3%
Stream Water	SHC-9	7/7/2019	18%	16%	11%	16%	8%
Stream Water	OC-19	12/17/2019	1%	0.5%	17%	1%	15%
Stream Water	WAC-1	12/19/2019	1%	1%	1%	2%	1%
Stream Water	WAC-3-20	3/13/2020	1%	0.5%	1%	0.2%	0.2%

Table 9: Municipal water chemical data. Sources are listed for multiple datasets.

WATERSHED	SITE TYPE	SITE/SAMPLE NAME	SAMPLE DATE	SOURCE	CONDUCTIVITY	PH	WATER TEMPERATURE
Waller	Municipal Wastewater (UN)	Manhole @ Waller and 15th	2/7/2011	City of Austin	856.3	8.4	19.4
Barton	Municipal Wastewater (UN)	Manhole @ Travis Country	3/7/2011	City of Austin	725.4	8.2	21.1
Slaughter	Municipal Wastewater (UN)	Manhole @ Circle C	2/7/2011	City of Austin	614.2	8.1	20.3
Slaughter	Municipal Wastewater (UN)	Manhole @ Circle C	2/7/2011	City of Austin			
Bull	Municipal Wastewater (UN)	Manhole @ Bull Creek and Loop 360	2/7/2011	City of Austin	655.0	7.7	17.6
Shoal	Municipal Wastewater (UN)	Manhole @ Spicewood and Mopac	2/7/2011	City of Austin	978.9	7.8	20.4
Bull	Municipal Wastewater (UN)	Manhole @ Bull Creek and Loop 360	2/7/2011	City of Austin	935.8	7.7	18.6
Slaughter	Municipal Wastewater (UN)	Manhole @ Slaughter Creek and IH 35	2/7/2011	City of Austin			
Shoal	Municipal Wastewater (UN)	Manhole @ Spicewood and Mopac	2/7/2011	City of Austin	1137.0	6.5	24.3

Table 9 (cont.)

WATERSHED	SITE TYPE	SITE/SAMPLE NAME	SAMPLE DATE	SOURCE	CONDUCTIVITY	PH	WATER TEMPERATURE
Slaughter	Municipal Wastewater (UN)	Manhole @ Slaughter Creek and IH 35	2/7/2011	City of Austin	855.0	8.1	29.8
Waller	Municipal Wastewater (UN)	Manhole @ Waller and 15th	2/7/2011	City of Austin	843.5	8.7	33.1
West Bull	Municipal Supply Water	MW-2	8/14/2002	Christian et al. (2011)			
Shoal	Municipal Supply Water	MW-3	6/30/2003	Christian et al. (2011)		9.5	
Harper's Branch	Municipal Supply Water	MW-4	7/24/2003	Christian et al. (2011)		9.6	
Barton	Municipal Supply Water	MW-5	7/25/2003	Christian et al. (2011)		7.8	
Slaughter	Municipal Supply Water	MW-6	8/1/2003	Christian et al. (2011)		9.5	
Williamson	Municipal Supply Water	MW-7	8/17/2003	Christian et al. (2011)		9.2	
Little Walnut	Municipal Supply Water	MW-8	9/1/2003	Christian et al. (2011)		9.5	
Waller	Municipal Supply Water	JTAP	9/24/2013	Senison (2014)			
Waller	Municipal Supply Water	JTAP	10/22/2013	Senison (2014)			

Table 9 (cont.)

WATERSHED	SITE TYPE	SITE/SAMPLE NAME	SAMPLE DATE	SOURCE	CONDUCTIVITY	PH	WATER TEMPERATURE
Waller	Municipal Supply Water	JTAP	11/23/2013	Senison (2014)			
Waller	Municipal Supply Water	MW-11	9/9/2003	Christian et al. (2011)		9.5	
Bull	Municipal Supply Water	MW-9	10/2/2003	Christian et al. (2011)			
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/20/2013	Senison (2014)			
Bull	Municipal Supply Water	TCB	8/28/2010	Senison (2014)		9.4	24.2
Bull	Municipal Supply Water	TCB	4/15/2011	Senison (2014)		9.3	26.2
Bull	Municipal Supply Water	SBK	7/25/2012	Senison (2014)	301.0	9.3	21.5
Bull	Municipal Supply Water	SBK	7/27/2012	Senison (2014)	321.0	9.4	29.4
Bull	Municipal Supply Water	SBK	8/10/2012	Senison (2014)	328.0	9.2	31.1
Bull	Municipal Supply Water	SBK	9/25/2012	Senison (2014)	333.0	9.4	29.1
Bull	Municipal Supply Water	CLB	6/21/2013	Senison (2014)	343.0	9.4	34.6
Williamson	Municipal Supply Water	TapWL5	7/9/2019	Loewald	274.2	9.6	25.5

Table 9 (cont.)

WATERSHED	SITE TYPE	SITE/SAMPLE NAME	SAMPLE DATE	SOURCE	CONDUCTIVITY	PH	WATER TEMPERATURE
Barton	Municipal Supply Water	TapBR4	7/7/2019	Loewald	271.5	9.1	36.8
Waller	Municipal Supply Water	TapWC1	7/9/2019	Loewald	271.3	8.9	28.2
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/14/2013	Senison (2014)			
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/15/2013	Senison (2014)			
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/17/2013	Senison (2014)			
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/18/2013	Senison (2014)			
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/21/2013	Senison (2014)			
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/22/2013	Senison (2014)			
Town Lake	Municipal Supply Water	Davis Water Treatment Plant - City Water (TR)	9/6/2002	Christian et al. (2011)	213.0	9.7	
Shoal	Municipal Supply Water	Green Water Treatment Plant - City Water (TR)	9/6/2002	Christian et al. (2011)	236.0	10.2	

Table 9 (cont.)

WATERSHED	SITE TYPE	SITE/SAMPLE NAME	SAMPLE DATE	SOURCE	CONDUCTIVITY	PH	WATER TEMPERATURE
Little Bee Creek	Municipal Supply Water	Ullrich Water Treatment Plant - City Water (TR)	9/6/2002	Christian et al. (2011)	306.0	9.7	
NA	Municipal Wastewater (UN)	City of Austin Wastewater	4/30/2011	Senison (2014)			
NA	Municipal Wastewater (UN)	City of Austin Wastewater	5/1/2011	Senison (2014)			
Onion Creek	Municipal Wastewater (TR)	Roy Kizer Reclaimed Water Pipe	7/23/2015	City of Austin			
NA	Municipal Wastewater (UN)	Govalle Waste Treatment Plant - raw influent sewage	9/6/2002	Christian et al. (2011)	724	7.5	30.9
Walnut Creek	Municipal Wastewater (UN)	Walnut Creek Waste Treatment Plant - raw influent sewage	9/6/2002	Christian et al. (2011)	740	7.3	29.1

Table 9 (cont.)

WATERSHED	SITE TYPE	SITE/SAMPLE NAME	SAMPLE DATE	Sr (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	Lab
Waller	Municipal Wastewater (UN)	Manhole @ Waller and 15th	2/7/2011	NM	28.4	21.2	60.9	NM	NA
Barton	Municipal Wastewater (UN)	Manhole @ Travis Country	3/7/2011	NM	20.2	16.8	47.9	16.3	NA
Slaughter	Municipal Wastewater (UN)	Manhole @ Circle C	2/7/2011	NM	16.9	15.8	49.0	NM	NA
Slaughter	Municipal Wastewater (UN)	Manhole @ Circle C	2/7/2011	NM	15.4	15.5	49.8	NM	NA
Bull	Municipal Wastewater (UN)	Manhole @ Bull Creek and Loop 360	2/7/2011	NM	38.5	21.1	53.7	NM	NA
Shoal	Municipal Wastewater (UN)	Manhole @ Spicewood and Mopac	2/7/2011	NM	25.9	20.7	41.8	NM	NA
Bull	Municipal Wastewater (UN)	Manhole @ Bull Creek and Loop 360	2/7/2011	NM	37.2	21.1	55.2	NM	NA
Slaughter	Municipal Wastewater (UN)	Manhole @ Slaughter Creek and IH 35	2/7/2011	NM	30.6	18.5	55.9	NM	NA
Shoal	Municipal Wastewater (UN)	Manhole @ Spicewood and Mopac	2/7/2011	NM	22.8	20.4	42.7	NM	NA

Table 9 (cont.)

WATERSHED	SITE TYPE	SITE/SAMPLE NAME	SAMPLE DATE	Sr (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	Lab
Slaughter	Municipal Wastewater (UN)	Manhole @ Slaughter Creek and IH 35	2/7/2011	NM	26.9	17.3	54.4	NM	NA
Waller	Municipal Wastewater (UN)	Manhole @ Waller and 15th	2/7/2011	NM	23.7	19.9	60.1	NM	NA
West Bull	Municipal Supply Water	MW-2	8/14/2002	0.1	14.5	5.3	10.2	3.2	ICP-Q-MS (UT DGS)
Shoal	Municipal Supply Water	MW-3	6/30/2003	0.1	11.6	15.5	19.7	3.3	ICP-Q-MS (UT DGS)
Harper's Branch	Municipal Supply Water	MW-4	7/24/2003	0.1	13.4	15.2	19.6	3.2	ICP-Q-MS (UT DGS)
Barton	Municipal Supply Water	MW-5	7/25/2003	0.4	49.2	19.8	19.4	3.2	ICP-Q-MS (UT DGS)
Slaughter	Municipal Supply Water	MW-6	8/1/2003	0.1	13.8	14.5	19.7	3.3	ICP-Q-MS (UT DGS)
Williamson	Municipal Supply Water	MW-7	8/17/2003	0.1	14.2	13.9	19.8	3.2	ICP-Q-MS (UT DGS)
Little Walnut	Municipal Supply Water	MW-8	9/1/2003	0.2	11.0	17.1	19.8	3.3	ICP-Q-MS (UT DGS)
Waller	Municipal Supply Water	JTAP	9/24/2013	0.1	10.9	18.6	29.9	5.1	ICP-Q-MS (UT DGS)
Waller	Municipal Supply Water	JTAP	10/22/2013	0.1	11.9	18.9	27.0	4.9	ICP-Q-MS (UT DGS)

Table 9 (cont.)

WATERSHED	SITE TYPE	SITE/SAMPLE NAME	SAMPLE DATE	Sr (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	Lab
Waller	Municipal Supply Water	JTAP	11/23/2013	0.2	16.1	16.4	22.9	4.5	ICP-Q-MS (UT DGS)
Waller	Municipal Supply Water	MW-11	9/9/2003	0.1	10.2	14.9	19.7	3.2	ICP-Q-MS (UT DGS)
Bull	Municipal Supply Water	MW-9	10/2/2003	0.1	10.7	15.3	20.2	3.2	ICP-Q-MS (UT DGS)
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/20/2013	0.2	37.0	21.0	55.0	NM	ICP-Q-MS (UT DGS)
Bull	Municipal Supply Water	TCB	8/28/2010	0.1	11.0	15.0	18.0	3.2	ICP-Q-MS (UT DGS)
Bull	Municipal Supply Water	TCB	4/15/2011	0.1	12.0	16.0	18.0	3.6	ICP-Q-MS (UT DGS)
Bull	Municipal Supply Water	SBK	7/25/2012	0.1	11.0	15.0	25.0	3.9	ICP-Q-MS (UT DGS)
Bull	Municipal Supply Water	SBK	7/27/2012	0.1	11.0	14.0	24.0	4.2	ICP-Q-MS (UT DGS)
Bull	Municipal Supply Water	SBK	8/10/2012	0.1	12.0	18.0	31.0	4.9	ICP-Q-MS (UT DGS)
Bull	Municipal Supply Water	SBK	9/25/2012	0.1	11.0	18.0	28.0	4.4	ICP-Q-MS (UT DGS)
Bull	Municipal Supply Water	CLB	6/21/2013	0.1	11.0	16.0	27.0	4.7	ICP-Q-MS (UT DGS)
Williamson	Municipal Supply Water	TapWL5	7/9/2019	0.1	11.7	11.8	16.5	3.9	ICP-Q-MS (UT DGS)

Table 9 (cont.)

WATERSHED	SITE TYPE	SITE/SAMPLE NAME	SAMPLE DATE	Sr (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	Lab
Barton	Municipal Supply Water	TapBR4	7/7/2019	0.1	11.7	11.7	16.3	4.0	ICP-Q-MS (UT DGS)
Waller	Municipal Supply Water	TapWC1	7/9/2019	0.1	9.3	11.8	16.7	3.9	ICP-Q-MS (UT DGS)
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/14/2013	0.2	15.0	16.0	50.0	20.0	ICP-Q-MS (UT DGS)
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/15/2013	0.2	27.0	17.0	54.0	16.0	ICP-Q-MS (UT DGS)
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/17/2013	0.4	24.0	20.0	60.0	14.0	ICP-Q-MS (UT DGS)
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/18/2013	0.2	25.0	16.0	63.0	18.0	ICP-Q-MS (UT DGS)
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/21/2013	0.2	23.0	20.0	43.0	14.0	ICP-Q-MS (UT DGS)
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/22/2013	0.1	24.0	16.0	105.0	26.0	ICP-Q-MS (UT DGS)
Town Lake	Municipal Supply Water	Davis Water Treatment Plant - City Water (TR)	9/6/2002	0.1	14.8	8.0	12.9	3.2	ICP-Q-MS (UT DGS)
Shoal	Municipal Supply Water	Green Water Treatment Plant - City Water (TR)	9/6/2002	0.1	14.7	9.7	13.0	3.1	ICP-Q-MS (UT DGS)

Table 9 (cont.)

WATERSHED	SITE TYPE	SITE/SAMPLE NAME	SAMPLE DATE	Sr (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	Lab
Little Bee Creek	Municipal Supply Water	Ullrich Water Treatment Plant - City Water (TR)	9/6/2002	0.1	12.6	8.5	10.9	3.3	ICP-Q-MS (UT DGS)
NA	Municipal Wastewater (UN)	City of Austin Wastewater	4/30/2011	0.1	31.0	18.0	62.0	14.0	LCRA
NA	Municipal Wastewater (UN)	City of Austin Wastewater	5/1/2011	0.2	34.0	17.0	85.0	12.0	LCRA
Onion Creek	Municipal Wastewater (TR)	Roy Kizer Reclaimed Water Pipe	7/23/2015	0.3	50.3	23.6	79.9	13.9	NA
NA	Municipal Wastewater (UN)	Govalle Waste Treatment Plant - raw influent sewage	9/6/2002	0.2	27.1	17.7	57.2	13.3	ICP-Q-MS (UT DGS)
Walnut Creek	Municipal Wastewater (UN)	Walnut Creek Waste Treatment Plant - raw influent sewage	9/6/2002	0.1	28.1	12.9	66.6	13.2	ICP-Q-MS (UT DGS)

Table 9 (cont.)

WATERSHED	SITE TYPE	SITE/SAMPLE NAME	SAMPLE DATE	SO4 (ppm)	Cl (ppm)	HCO3 (ppm)	NO3 (ppm)	F (ppm)	Lab
Waller	Municipal Wastewater (UN)	Manhole @ Waller and 15th	2/7/2011	67.7	NM	248.0	NM	0.7	NA
Barton	Municipal Wastewater (UN)	Manhole @ Travis Country	3/7/2011	33.7	NM	222.0	NM	0.5	NA
Slaughter	Municipal Wastewater (UN)	Manhole @ Circle C	2/7/2011	46.5	NM	163.0	NM	0.7	NA
Slaughter	Municipal Wastewater (UN)	Manhole @ Circle C	2/7/2011	43.9	NM	154.0	NM	0.7	NA
Bull	Municipal Wastewater (UN)	Manhole @ Bull Creek and Loop 360	2/7/2011	49.7	NM	231.0	NM	0.5	NA
Shoal	Municipal Wastewater (UN)	Manhole @ Spicewood and Mopac	2/7/2011	51.8	NM	189.0	NM	0.5	NA
Bull	Municipal Wastewater (UN)	Manhole @ Bull Creek and Loop 360	2/7/2011	49.8	NM	231.0	NM	0.5	NA
Slaughter	Municipal Wastewater (UN)	Manhole @ Slaughter Creek and IH 35	2/7/2011	50.0	NM	274.0	NM	0.6	NA
Shoal	Municipal Wastewater (UN)	Manhole @ Spicewood and Mopac	2/7/2011	51.5	NM	186.0	NM	0.6	NA

Table 9 (cont.)

WATERSHED	SITE TYPE	SITE/SAMPLE NAME	SAMPLE DATE	SO4 (ppm)	Cl (ppm)	HCO3 (ppm)	NO3 (ppm)	F (ppm)	Lab
Slaughter	Municipal Wastewater (UN)	Manhole @ Slaughter Creek and IH 35	2/7/2011	49.4	NM	272.0	NM	0.6	NA
Waller	Municipal Wastewater (UN)	Manhole @ Waller and 15th	2/7/2011	67.2	NM	245.0	NM	0.7	NA
West Bull	Municipal Supply Water	MW-2	8/14/2002	20.3	20.5	43.2	0.2	1.0	Dionex ICS (UMN)
Shoal	Municipal Supply Water	MW-3	6/30/2003	27.7	34.3	70.0	0.2	0.8	Dionex ICS (UMN)
Harper's Branch	Municipal Supply Water	MW-4	7/24/2003	27.8	34.2	75.4	0.2	0.8	Dionex ICS (UMN)
Barton	Municipal Supply Water	MW-5	7/25/2003	31.0	36.8	185.4	0.3	0.7	Dionex ICS (UMN)
Slaughter	Municipal Supply Water	MW-6	8/1/2003	28.2	34.2	69.8	0.2	0.9	Dionex ICS (UMN)
Williamson	Municipal Supply Water	MW-7	8/17/2003	28.3	35.0	67.6	0.2	0.8	Dionex ICS (UMN)
Little Walnut	Municipal Supply Water	MW-8	9/1/2003	27.6	34.7	77.1	0.1	0.6	Dionex ICS (UMN)
Waller	Municipal Supply Water	JTAP	9/24/2013	30.3	44.0	65.1	0.2	0.6	Dionex ICS (UMN)

Table 9 (cont.)

WATERSHED	SITE TYPE	SITE/SAMPLE NAME	SAMPLE DATE	SO4 (ppm)	Cl (ppm)	HCO3 (ppm)	NO3 (ppm)	F (ppm)	Lab
Waller	Municipal Supply Water	JTAP	10/22/2013	30.3	45.4	61.6	0.4	0.5	Dionex ICS (UMN)
Waller	Municipal Supply Water	JTAP	11/23/2013	33.7	39.9	63.2	1.4	0.6	Dionex ICS (UMN)
Waller	Municipal Supply Water	MW-11	9/9/2003	27.2	34.9	65.6	0.1	0.6	Dionex ICS (UMN)
Bull	Municipal Supply Water	MW-9	10/2/2003	28.3	35.4	65.6	0.0	1.1	Dionex ICS (UMN)
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/20/2013	50.0	79.0	141.0	NM	0.5	HPLC (UT DGS)
Bull	Municipal Supply Water	TCB	8/28/2010	22.0	27.0	68.0	1.1	0.8	HPLC (UT DGS)
Bull	Municipal Supply Water	TCB	4/15/2011	28.0	30.0	74.0	0.6	0.6	HPLC (UT DGS)
Bull	Municipal Supply Water	SBK	7/25/2012	32.0	43.0	60.0	0.8	0.7	HPLC (UT DGS)
Bull	Municipal Supply Water	SBK	7/27/2012	30.0	44.0	60.0	2.0	0.7	HPLC (UT DGS)
Bull	Municipal Supply Water	SBK	8/10/2012	30.0	41.0	64.0	0.5	0.6	HPLC (UT DGS)

Table 9 (cont.)

WATERSHED	SITE TYPE	SITE/SAMPLE NAME	SAMPLE DATE	SO4 (ppm)	Cl (ppm)	HCO3 (ppm)	NO3 (ppm)	F (ppm)	Lab
Bull	Municipal Supply Water	SBK	9/25/2012	29.0	43.0	76.0	0.8	0.7	HPLC (UT DGS)
Bull	Municipal Supply Water	CLB	6/21/2013	31.0	43.0	66.0	NM	0.6	HPLC (UT DGS)
Williamson	Municipal Supply Water	TapWL5	7/9/2019	24.6	32.3	61.6	8.4	0.7	IC (UT CAEE)
Barton	Municipal Supply Water	TapBR4	7/7/2019	24.8	32.7	62.9	8.2	0.8	IC (UT CAEE)
Waller	Municipal Supply Water	TapWC1	7/9/2019	23.7	32.0	66.4	8.5	0.9	IC (UT CAEE)
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/14/2013	44.0	63.0	94.0	0.2	0.7	HPLC (UT DGS)
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/15/2013	49.0	70.0	166.0	0.3	0.6	HPLC (UT DGS)
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/17/2013	67.0	73.0	149.0	0.3	0.7	HPLC (UT DGS)
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/18/2013	38.0	81.0	165.0	NM	0.4	HPLC (UT DGS)
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/21/2013	52.0	57.0	113.0	0.2	0.6	HPLC (UT DGS)

Table 9 (cont.)

WATERSHED	SITE TYPE	SITE/SAMPLE NAME	SAMPLE DATE	SO4 (ppm)	Cl (ppm)	HCO3 (ppm)	NO3 (ppm)	F (ppm)	Lab
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/21/2013	52.0	57.0	113.0	0.2	0.6	HPLC (UT DGS)
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/22/2013	32.0	167.0	130.0	0.1	0.5	HPLC (UT DGS)
Town Lake	Municipal Supply Water	Davis Water Treatment Plant - City Water (TR)	9/6/2002	21.1	22.3	50.0	0.6	NM	Dionex ICS (UMN)
Shoal	Municipal Supply Water	Green Water Treatment Plant - City Water (TR)	9/6/2002	19.1	23.4	58.3	0.9	NM	Dionex ICS (UMN)
Little Bee Creek	Municipal Supply Water	Ullrich Water Treatment Plant - City Water (TR)	9/6/2002	19.1	22.5	53.7	0.7	NM	Dionex ICS (UMN)
NA	Municipal Wastewater (UN)	City of Austin Wastewater	4/30/2011	41.0	63.0	156.0	0.4	1.0	LCRA
NA	Municipal Wastewater (UN)	City of Austin Wastewater	5/1/2011	120.0	68.0	135.0	2.1	1.2	LCRA
Onion Creek	Municipal Wastewater (TR)	Roy Kizer Reclaimed Water Pipe	7/23/2015	72.6	111.0	127.0	NM	1.2	NA
NA	Municipal Wastewater (UN)	Govalle Waste Treatment Plant - raw influent sewage	9/6/2002	19.8	66.9	241.0	0.4	NM	Dionex ICS (UMN)
Walnut Creek	Municipal Wastewater (UN)	Walnut Creek Waste Treatment Plant - raw influent sewage	9/6/2002	15.1	67.8	204.0	1.5	NM	Dionex ICS (UMN)

Table 9 (cont.)

WATERSHED	SITE TYPE	SITE/SAMPLE NAME	SAMPLE DATE	Calculated Charge Balance	87Sr/86Sr	2σ	NBS-987
Waller	Municipal Wastewater (UN)	Manhole @ Waller and 15th	2/7/2011	2.8	NM	NM	NM
Barton	Municipal Wastewater (UN)	Manhole @ Travis Country	3/7/2011	5.9	NM	NM	NM
Slaughter	Municipal Wastewater (UN)	Manhole @ Circle C	2/7/2011	7.7	NM	NM	NM
Slaughter	Municipal Wastewater (UN)	Manhole @ Circle C	2/7/2011	9.7	NM	NM	NM
Bull	Municipal Wastewater (UN)	Manhole @ Bull Creek and Loop 360	2/7/2011	10.8	NM	NM	NM
Shoal	Municipal Wastewater (UN)	Manhole @ Spicewood and Mopac	2/7/2011	7.0	NM	NM	NM
Bull	Municipal Wastewater (UN)	Manhole @ Bull Creek and Loop 360	2/7/2011	10.7	NM	NM	NM
Slaughter	Municipal Wastewater (UN)	Manhole @ Slaughter Creek and IH 35	2/7/2011	-0.5	NM	NM	NM
Shoal	Municipal Wastewater (UN)	Manhole @ Spicewood and Mopac	2/7/2011	6.2	NM	NM	NM
Slaughter	Municipal Wastewater (UN)	Manhole @ Slaughter Creek and IH 35	2/7/2011	-3.4	NM	NM	NM
Waller	Municipal Wastewater (UN)	Manhole @ Waller and 15th	2/7/2011	0.0	NM	NM	NM

Table 9 (cont.)

WATERSHED	SITE TYPE	SITE/SAMPLE NAME	SAMPLE DATE	Calculated Charge Balance	87Sr/86Sr	2σ	NBS-987
West Bull	Municipal Supply Water	MW-2	8/14/2002	-2.0	0.708775	0.000007	0.710255
Shoal	Municipal Supply Water	MW-3	6/30/2003	1.4	0.708893	0.00001	0.710263
Harper's Branch	Municipal Supply Water	MW-4	7/24/2003	0.9	0.708880	0.000009	0.710258
Barton	Municipal Supply Water	MW-5	7/25/2003	2.8	0.709057	0.000008	0.710258
Slaughter	Municipal Supply Water	MW-6	8/1/2003	1.8	0.708930	0.000007	0.710258
Williamson	Municipal Supply Water	MW-7	8/17/2003	1.4	0.708897	0.000007	0.710268
Little Walnut	Municipal Supply Water	MW-8	9/1/2003	1.2	0.708841	0.000007	0.710263
Waller	Municipal Supply Water	JTAP	9/24/2013	8.5	NM	NM	NM
Waller	Municipal Supply Water	JTAP	10/22/2013	8.1	NM	NM	NM
Waller	Municipal Supply Water	JTAP	11/23/2013	5.9	NM	NM	NM
Waller	Municipal Supply Water	MW-11	9/9/2003	0.57	0.708829	0.000007	0.710263

Table 9 (cont.)

WATERSHED	SITE TYPE	SITE/SAMPLE NAME	SAMPLE DATE	Calculated Charge Balance	87Sr/86Sr	2σ	NBS-987
Bull	Municipal Supply Water	MW-9	10/2/2003	0.9	0.708787	0.000008	0.710268
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/20/2013	3.3	0.708138	0.000008	0.710264
Bull	Municipal Supply Water	TCB	8/28/2010	5.4	0.709096	0.000005	0.710264
Bull	Municipal Supply Water	TCB	4/15/2011	2.3	0.709340	0.000006	0.710264
Bull	Municipal Supply Water	SBK	7/25/2012	1.2	0.709190	0.000006	0.710264
Bull	Municipal Supply Water	SBK	7/27/2012	-0.8	0.709230	0.000006	0.710264
Bull	Municipal Supply Water	SBK	8/10/2012	11.0	0.709230	0.000006	0.710264
Bull	Municipal Supply Water	SBK	9/25/2012	4.2	0.709522	0.000006	0.710264
Bull	Municipal Supply Water	CLB	6/21/2013	3.4	0.709417	0.000006	0.71022
Williamson	Municipal Supply Water	TapWL5	7/9/2019	-4.47	0.709092	0.000006	0.710248
Barton	Municipal Supply Water	TapBR4	7/7/2019	-5.46	NM	NM	NM

Table 9 (cont.)

WATERSHED	SITE TYPE	SITE/SAMPLE NAME	SAMPLE DATE	Calculated Charge Balance	87Sr/86Sr	2σ	NBS-987
Waller	Municipal Supply Water	TapWC1	7/9/2019	-7.97	0.709034	0.000006	0.710248
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/14/2013	5.5	0.708984	0.000008	0.710264
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/15/2013	-2.0	0.707938	0.000008	0.710264
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/17/2013	-0.9	0.708987	0.000008	0.710264
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/18/2013	-0.2	0.708840	0.000008	0.710264
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/21/2013	4.9	0.708690	0.000002	0.710264
NA	Municipal Wastewater (UN)	City of Austin Wastewater	6/22/2013	1.5	0.708770	0.000002	0.710264
Town Lake	Municipal Supply Water	Davis Water Treatment Plant - City Water (TR)	9/6/2002	3.9	NM	NM	NM
Shoal	Municipal Supply Water	Green Water Treatment Plant - City Water (TR)	9/6/2002	3.8	NM	NM	NM
Little Bee Creek	Municipal Supply Water	Ullrich Water Treatment Plant - City Water (TR)	9/6/2002	-0.6	NM	NM	NM
NA	Municipal Wastewater (UN)	City of Austin Wastewater	4/30/2011	7.56	0.708757	0.000006	0.710264

Table 9 (cont.)

WATERSHED	SITE TYPE	SITE/SAMPLE NAME	SAMPLE DATE	Calculated Charge Balance	87Sr/86Sr	2σ	NBS-987
NA	Municipal Wastewater (UN)	City of Austin Wastewater	5/1/2011	2.84	0.708467	0.000008	0.710264
Onion Creek	Municipal Wastewater (TR)	Roy Kizer Reclaimed Water Pipe	7/23/2015	10.1	NM	NM	NM
NA	Municipal Wastewater (UN)	Govalle Waste Treatment Plant - raw influent sewage	9/6/2002	-7.7	0.708671	0.000006	0.710255
Walnut Creek	Municipal Wastewater (UN)	Walnut Creek Waste Treatment Plant - raw influent sewage	9/6/2002	-2.5	0.708102	0.000008	0.710255

NM = not measured

NA = not available

TR = treated

UN = untreated

Table 10: Stream and spring water chemical data. Sources are listed for multiple datasets.

Watershed	Site Classification	Site ID	Collection Date	Conductivity (uS/cm)	pH	Water temperature (deg. C)	Charge Balance (% error)
Waller	Stream Water	WAC-7	10/4/2001	901	8.01	23.4	3.43
Waller	Stream Water	WAC-7	9/3/2018	629.3	8.52	26.8	-1.54
Waller	Stream Water	WAC-7	9/9/2018	84.8	8.1	25	0.78
Waller	Stream Water	WAC-7	10/12/2018	557.5	8.51	26.1	-2.93
Waller	Stream Water	WAC-7	12/19/2019	753.4	7.74	8.6	-0.37
Waller	Stream Water	WAC-7	7/31/2018	1847	8.41	27.3	6.80
Waller	Stream Water	WAC-5b-20	7/11/2018	558.4	8.21	26.2	-8.23
Waller	Stream Water	WAC-5b-20	9/3/2018	779.2	8.06	26.7	1.44
Waller	Stream Water	WAC-5	11/29/2018	968.8	7.88	17.7	-2.64
Waller	Stream Water	WAC-2	8/16/2001	842	8.01	29.1	5.13
Waller	Stream Water	WAC-2	10/3/2001	906	8.17	23.2	5.19
Waller	Stream Water	WAC-1	10/3/2001	1141	7.81	24.6	3.68
Waller	Stream Water	CF	8/11/2013				0.43
Waller	Stream Water	CF	9/24/2013				-0.20
Waller	Stream Water	CF	10/22/2013				8.02
Waller	Stream Water	CF	11/21/2013				2.07
Waller	Pipe Outfall	P104	9/24/2013				4.14
Waller	Stream Water	CLASPRING	10/12/2018	2322	7.64	25	-0.64
Waller	Stream Water	WAC-3-20	7/11/2018	501.3	7.89	26	-1.39
Waller	Stream Water	WAC-3-20	7/31/2018	648	7.89	27	-1.28
Waller	Stream Water	WAC-3-20	9/3/2018	646.4	8.21	26	0.73
Waller	Stream Water	WAC-3-20	9/9/2018	259.1	8.33	25.2	-6.52
Waller	Stream Water	WAC-3-20	10/12/2018	539.2	8.07	24.8	9.32
Waller	Stream Water	WAC-3-20	12/19/2019	915.8	7.25	7.4	-0.55
Waller	Stream Water	WAC-3-20	11/29/2018	973.4	7.82	18.1	-1.52

Table 10 (cont.)

Watershed	Site Classification	Site ID	Collection Date	Conductivity (uS/cm)	pH	Water temperature (deg. C)	Charge Balance (% error)
Waller	Stream Water	DSIM	7/11/2018	334.1	8.24	26.2	-1.05
Waller	Stream Water	DSIM	9/9/2018	149.7	9	25.3	0.12
Waller	Stream Water	WAC-5b-20	10/12/2018	696.2	8.25	24.5	-0.40
Waller	Stream Water	WAC-5b-20	12/5/2018	885.3	5.75	15.5	-0.38
Waller	Stream Water	WAC-1-20	7/11/2018	384.5	7.51	25.6	-0.51
Waller	Stream Water	WAC-1-20	7/31/2018	770.8	7.63	27	-1.08
Waller	Stream Water	WAC-1-20	9/9/2018	157.1	9.55	25.3	-0.25
Waller	Stream Water	WAC-1-20	12/19/2019	759	6.56	8.9	0.39
Waller	Stream Water	EASTWOODS	9/9/2018	138.4	7.88	25.6	3.04
Waller	Stream Water	EASTWOODS	7/11/2018	444.5	8.07	26	0.10
Waller	Stream Water	EC	8/11/2013				4.42
Waller	Stream Water	EC	9/24/2013				5.04
Waller	Stream Water	EC	10/22/2013				8.33
Waller	Stream Water	EC	11/21/2013				2.73
Waller	Stream Water	WAC-3	10/3/2001	915	8.06	21.7	3.60
Waller	Stream Water	HD	8/11/2013				8.92
Waller	Stream Water	HD	9/24/2013				7.12
Waller	Stream Water	HD	10/22/2013				7.55
Waller	Stream Water	HD	11/21/2013				2.16
Waller	Stream Water	HH	8/11/2013				1.84
Waller	Stream Water	HH	9/24/2013				3.25
Waller	Stream Water	HH	10/22/2013				3.79
Waller	Stream Water	HH	11/21/2013				2.73
Waller	Stream Water	WAC-4	10/2/2001	825	8.14	20.9	4.52
Waller	Stream Water	WAC-1	7/11/2018	424.1	7.69	25.5	-0.48

Table 10 (cont.)

Watershed	Site Classification	Site ID	Collection Date	Conductivity (uS/cm)	pH	Water temperature (deg. C)	Charge Balance (% error)
Waller	Stream Water	WAC-1	9/9/2018	209.3	7.56	25.5	2.16
Waller	Stream Water	WAC-1	10/12/2018	672.4	7.92	28.4	3.09
Waller	Stream Water	WAC-1	11/29/2018	1048	7.34	18.8	0.39
Waller	Stream Water	WAC-1	6/27/2019	791.7	7.72	26.8	-1.77
Waller	Stream Water	WAC-1	12/19/2019	791.7	7.72	26.8	-2.30
Waller	Stream Water	WAC-2	7/11/2018	422.4	8.05	25.6	-6.44
Waller	Pipe Outfall	P104	8/11/2013				10.15
Waller	Stream Water	USIM	7/11/2018	404.1	8.18	25.5	-0.94
Waller	Stream Water	USRS	7/11/2018	529	7.5	24.7	-1.09
Waller	Stream Water	WAC-10	7/9/2019				-2.26
Waller	Stream Water	WD	8/11/2013				2.96
Bull	Urban Tributary	AE	7/24/2012	664	8.43	31.1	2.57
Waller	Pipe Outfall	P105	10/12/2018	337.2	8.78	24.8	1.04
Bull	Urban Tributary	AE	7/27/2012	752	8.01	32.9	3.57
Bull	Urban Tributary	AN	7/24/2012	928	8.29	31.7	0.99
Bull	Urban Tributary	AN	7/27/2012	942	7.89	33.6	0.64
Bull	Urban Tributary	AS	7/24/2012	732	7.35	27.4	1.14
Bull	Urban Tributary	AS	7/27/2012	751	7.97	27.8	0.90
Bull	Urban Tributary	AS	8/10/2012	804	7.86	27.1	5.02
Bull	Urban Tributary	AS	9/25/2012	797	7.85	24.4	4.27
Waller	Stream Water	WD	9/24/2013				2.66
Waller	Stream Water	WD	10/22/2013				7.67
Waller	Stream Water	WD	11/21/2013				2.16
Waller	Pipe Outfall	P105	8/11/2013				8.44
Waller	Stream Water	WAC-6	8/16/2001	625	8.17	28.5	3.07

Table 10 (cont.)

Watershed	Site Classification	Site ID	Collection Date	Conductivity (uS/cm)	pH	Water temperature (deg. C)	Charge Balance (% error)
Waller	Pipe Outfall	P105	9/24/2013				8.11
Waller	Pipe Outfall	P105	10/22/2013				8.33
Waller	Stream Water	WAC-6	9/1/2001	706	8.06	26.3	4.91
Waller	Pipe Outfall	P27	7/5/2018	577.2	6.47	26.1	5.56
Waller	Pipe Outfall	P27	9/3/2018	508.3	8.81	26.7	-1.50
Waller	Pipe Outfall	P27	10/12/2018	471.4	8.73	25.6	-3.95
Waller	Pipe Outfall	P27	12/5/2018	440.6	6.3	17.4	-1.91
Waller	Pipe Outfall	P27	8/11/2013				3.90
Waller	Pipe Outfall	P27	9/24/2013				2.41
Waller	Pipe Outfall	P27	10/22/2013				2.40
Waller	Pipe Outfall	WAC-5a-20	7/5/2018	559.2	7.5	25.8	-3.12
Waller	Pipe Outfall	WAC-5a-20	7/31/2018	1048	8.46	26.2	-1.96
Waller	Pipe Outfall	WAC-5a-20	9/3/2018	942.2	8.6	26.6	2.28
Waller	Pipe Outfall	WAC-5a-20	10/12/2018	864.3	8.46	25.2	0.42
Waller	Pipe Outfall	WAC-5a-20	12/5/2018	776.2	6.26	16.9	-4.69
Waller	Pipe Outfall	WAC-5a-20	8/11/2013				2.68
Waller	Pipe Outfall	WAC-5a-20	9/24/2013				0.99
Waller	Pipe Outfall	WAC-5a-20	10/22/2013				3.92
Bull	Urban Tributary	AS	3/7/2013	764	7.44	13.6	3.98
Waller	Stream Water	WAC-6	10/2/2001	1051	8.08	21.7	3.30
Waller	Stream Water	WAC-6	10/4/2001	944	8.1	23.2	3.50
Waller	Stream Water	WAC-6	10/5/2001	956	7.92	22.5	2.95
Waller	Stream Water	WAC-6	10/6/2001	938	8.04	19	3.22
Waller	Stream Water	WAC-6	4/29/2002	1014	7.9	26.5	-0.05
Bull	Urban Tributary	AS	6/21/2013	778	7.6	24.2	2.73

Table 10 (cont.)

Watershed	Site Classification	Site ID	Collection Date	Conductivity (uS/cm)	pH	Water temperature (deg. C)	Charge Balance (% error)
Waller	Stream Water	WAC-6	6/16/2002	824	7.78	25.2	-0.10
Waller	Stream Water	WAC-6	6/17/2002	440	7.99	26.2	1.83
Waller	Stream Water	WAC-6	6/25/2002	752	8.22	27.4	4.48
Bull	Urban Spring	BW	8/29/2010	895	7.26	22.71	5.32
Bull	Urban Spring	BW	4/12/2011	895	7.2		2.99
Bull	Urban Tributary	CC	7/27/2012	1036	7.65	23	2.15
Bull	Urban Tributary	CC	7/24/2012	1013	7.75	22.6	1.65
Bull	Rural Tributary	ED/BUC-2	7/24/2012	586	8.12	25.8	2.14
Bull	Rural Tributary	ED/BUC-2	7/27/2012	652	8.06	26	2.10
Bull	Rural Tributary	EM	7/24/2012	632	7.42	25.8	0.56
Bull	Rural Tributary	EM	7/27/2012	646	7.43	24.4	2.38
Bull	Rural Tributary	EN	7/24/2012	547	8.02	26.7	0.47
Bull	Rural Tributary	EN	7/27/2012	580	7.72	26.4	3.40
Bull	Urban Tributary	FB	3/7/2013	886	7.3	18.9	3.37
Bull	Urban Tributary	FB	6/21/2013	897	7.2	20.8	2.61
Bull	Urban Tributary	FE	3/7/2013	723	7.9	13.1	5.95
Bull	Urban Tributary	FE	6/21/2013	625	7.9	24.5	-0.21
Bull	Urban Tributary	FE	7/24/2012	732	7.87	24.9	2.67
Bull	Urban Tributary	FE	7/27/2012	747	7.82	25.3	1.75
Bull	Urban Tributary	FE	8/10/2012	764	7.7	27.3	4.55
Bull	Urban Tributary	FE	8/23/2012	694	7.58	24.1	3.60
Bull	Urban Tributary	FE	9/25/2012	708	7.91	23.6	4.35
Bull	Urban Tributary	FG	3/7/2013	653	7.95	15	3.15
Bull	Urban Tributary	FG	6/21/2013	593	8.2	24.6	3.93
Bull	Rural Spring	FK	8/23/2010	594	7.31	21.62	3.65

Table 10 (cont.)

Watershed	Site Classification	Site ID	Collection Date	Conductivity (uS/cm)	pH	Water temperature (deg. C)	Charge Balance (% error)
Bull	Rural Spring	FK	4/12/2011	571	7.2		4.33
Bull	Urban Tributary	FN	3/7/2013	574	8.2	15.4	-0.59
Bull	Urban Tributary	FN	6/21/2013	597	8.1	25	2.20
Bull	Urban Tributary	FN	7/24/2012	674	8.14	26.2	0.45
Bull	Urban Tributary	FN	7/27/2012	682	8.15	26.2	1.83
Bull	Urban Tributary	FN	8/10/2012	692	8.1	29.2	1.32
Bull	Urban Tributary	FN	8/23/2012	613	7.98	23.8	4.12
Bull	Urban Tributary	FN	9/25/2012	527	8.37	25.8	4.29
Bull	Urban Tributary	FW	7/24/2012	860	7.41	26.1	2.03
Bull	Urban Tributary	FW	7/27/2012	906	7.32	25.1	1.87
Bull	Urban Spring	FY	8/29/2010	632	6.87	19.79	4.36
Bull	Urban Spring	FY	4/15/2011	611	6.9		1.53
Bull	Rural Spring	LN	8/24/2010	591	7.26	21.66	1.39
Bull	Rural Spring	LN	4/12/2011	597	7		3.78
Bull	Rural Spring	LR	8/28/2010	637	7.18	22.17	4.71
Bull	Rural Spring	LR	4/12/2011	608	7.1		2.46
Bull	Urban Tributary	MV	7/24/2012	702	7.77	24.2	2.59
Bull	Urban Tributary	MV	7/27/2012	734	7.42	24.2	1.98
Bull	Urban Tributary	MV	8/10/2012	791	7.9	26.6	3.12
Bull	Urban Tributary	MV	9/25/2012	740	8.09	24.2	6.50
Bull	Urban Tributary	MV	3/7/2013	738	7.95	17.4	1.02
Bull	Urban Tributary	MV	6/21/2013	724	7.6	22.7	2.75
Bull	Urban Tributary	PC	3/7/2013	767	7.92	14.7	3.96
Bull	Urban Tributary	PC	6/21/2013	854	7.9	25.5	3.50
Bull	Rural Tributary	PN	3/7/2013	547	7.55	17.2	2.42

Table 10 (cont.)

Watershed	Site Classification	Site ID	Collection Date	Conductivity (uS/cm)	pH	Water temperature (deg. C)	Charge Balance (% error)
Bull	Rural Tributary	PN	6/21/2013	588	7.8	20.4	3.29
Bull	Urban Spring	SH	8/24/2010	1050	7.39		4.25
Bull	Urban Spring	SH	4/12/2011	1056	7.5		3.50
Waller	Stream Water	WAC-6	6/27/2002	336	7.98	27.1	3.19
Bull	Urban Spring	TB	8/29/2010	854	6.81	20.36	2.17
Bull	Urban Spring	TB	4/12/2011	854	6.8		4.62
Bull	Urban Spring	TF	8/24/2010	682	7.29	22.9	1.09
Bull	Urban Spring	TF	4/12/2011	687	6.9		3.27
Bull	Urban Spring	TL	8/28/2010	777	6.81	22.14	7.00
Bull	Urban Spring	TL	4/22/2011	753	6.9		5.67
Bull	Urban Tributary	TR	7/24/2012	835	7.61	22.4	1.58
Bull	Urban Tributary	TR	7/27/2012	875	7.59	23.5	3.15
Bull	Urban Tributary	TR	8/10/2012	800	8.1	29.8	6.11
Bull	Urban Tributary	TR	9/25/2012	840	8.04	26	10.72
Bull	Urban Spring	TS/BUC-1	8/24/2010	1000	7.09	23.64	2.22
Bull	Urban Spring	TS/BUC-1	4/12/2011	1074	7.4		6.94
Bull	Urban Spring	TT/BUC-3	8/28/2010	777	7.14	21.09	6.35
Bull	Urban Spring	TW	8/19/2010	989	6.99		2.12
Waller	Stream Water	WAC-6	5/10/2013				3.13
Bull	Urban Spring	TW	4/12/2011	885	7.3		5.40
Onion	Stream Water	OC-1	4/15/2001	522	8.04	27.6	0.83
Onion	Stream Water	OC-1	3/14/2002	525	8.12	19.9	2.03
Onion	Stream Water	OC-1	12/17/2019	526.5	7.09	7.6	-2.94
Onion	Stream Water	OC-11	4/6/2001	506	8.27	24.2	3.57
Onion	Stream Water	OC-13	4/6/2001	497	8.3	23.4	0.51

Table 10 (cont.)

Watershed	Site Classification	Site ID	Collection Date	Conductivity (uS/cm)	pH	Water temperature (deg. C)	Charge Balance (% error)
Onion	Stream Water	OC-14	4/9/2001	489	8.23	22.9	1.38
Onion	Stream Water	OC-14	3/14/2002	487	8.34	20.6	2.17
Onion	Stream Water	OC-15	3/17/2002	461	8.39	17.8	2.74
Onion	Stream Water	OC-15	7/7/2019	400.1	8.34	30.2	-2.76
Onion	Stream Water	OC-15	4/11/2001	471	8.28	22.6	-9.49
Onion	Stream Water	OC-16	3/17/2002	395	8.55	17	3.15
Onion	Stream Water	OC-16	4/9/2001	433	8.43	26	-9.93
Onion	Stream Water	OC-17	4/9/2001	429	8.32	25.1	-10.45
Onion	Stream Water	OC-18	4/11/2001	466	7.96	22.3	-8.61
Onion	Stream Water	OC-19	3/17/2002	621	7.85	17.2	1.96
Onion	Stream Water	OC-19	7/7/2019	514.2	7.92	28.6	-2.26
Onion	Stream Water	OC-19	12/17/2019	537.7	7.82	11.9	-3.15
Onion	Stream Water	OC-2	3/14/2002	499	8.3	20.5	2.13
Onion	Stream Water	OC-21	4/8/2001	619	7.95	25.2	2.39
Onion	Stream Water	OC-21	7/2/2019	516.6	7.8	31	-2.94
Onion	Stream Water	OC-21	12/17/2019	744.7	7.87	13.3	-5.83
Onion	Stream Water	OC-22	3/17/2002	684	7.97	18	1.89
Onion	Stream Water	OC-22	12/17/2019	756.2	8.07	13.6	-0.06
Onion	Stream Water	OC-23	3/17/2002	750	7.79	17.5	2.81
Onion	Stream Water	OC-3	4/15/2001	489	7.93	25.8	1.82
Onion	Stream Water	OC-4	4/15/2001	461	8.12	27.2	1.02
Onion	Stream Water	OC-5	4/15/2001	512	7.93	24.8	0.88
Onion	Stream Water	OC-5	3/17/2002	543	7.83	17.7	2.92
Shoal	Stream Water	SHCK29th	7/7/2019	796.6	7.72	29	-0.82
Shoal	Stream Water	SHC-3	7/7/2019	331.1	8.25	30	-2.87

Table 10 (cont.)

Watershed	Site Classification	Site ID	Collection Date	Conductivity (uS/cm)	pH	Water temperature (deg. C)	Charge Balance (% error)
Shoal	Stream Water	SHC-9	7/7/2019	570.4	7.98	31.5	-3.76
Williamson	Stream Water	WIC-8	7/7/2019	808	7.93	27.2	0.75
Williamson	Stream Water	WIC-5	7/7/2019	435.9	6.75	25.2	-5.70
Williamson	Stream Water	WIC-2	7/7/2019	640.1	7.01	25.1	-0.79
Barton	Stream Water	BAC-1	8/12/2002	629	7.55	26.3	2.95
Barton	Stream Water	BAC-5	7/7/2019	602.1	7.04	28.9	-4.15
Barton	Stream Water	BRCKGbMP	7/7/2019	528.2	7.68	32	-3.09
Barton	Stream Water	BAC-11	7/7/2019	650.2	6.77	29.1	-2.19
Bull	Urban Tributary	BLCKHwy360	7/3/2019	512.4	7.82	30.1	-1.95
Bull	Urban Tributary	BUC-4	7/3/2019	523.2	8.04	29.2	4.35
Bull	Rural Tributary	BUC-2	7/3/2019	562.1	7.13	29.6	-1.54
Waller	Stream Water	WAC-6	6/23/2013				7.54
Waller	Stream Water	WAC-6	7/14/2013				4.08
Shoal	Stream Water	SHC-1	10/31/2001	678	7.77	19.8	-0.79
Shoal	Stream Water	SHC-2	10/31/2001	575	7.95	22.1	1.38
Shoal	Stream Water	SHC-3	10/31/2001	529	8.4	18.9	1.83
Shoal	Stream Water	SHC-4	10/31/2001	785	7.64	19	-0.21
Shoal	Stream Water	SHC-4	11/2/2001	828	7.58	22.2	3.65
Shoal	Stream Water	SHC-4	11/6/2001	872	7.59	20.1	0.44
Shoal	Stream Water	SHC-5	11/2/2001	820	7.93	24	1.94
Shoal	Stream Water	SHC-6	11/2/2001	857	7.96	24.6	1.59
Shoal	Stream Water	SHC-7	11/6/2001	866	7.47	19.2	2.18
Shoal	Stream Water	SHC-8	10/31/2001	1038	7.91	20	4.27
Shoal	Stream Water	SHC-8	11/6/2001	797	8.33	20.8	1.03
Shoal	Stream Water	SHC-9	11/6/2001	727	7.61	23	1.99

Table 10 (cont.)

Watershed	Site Classification	Site ID	Collection Date	Conductivity (uS/cm)	pH	Water temperature (deg. C)	Charge Balance (% error)
Shoal	Stream Water	SHC-12	11/6/2001	669	7.76	22.6	2.50
Williamson	Stream Water	WIC-1	1/29/2002	875	7.98	18.8	1.30
Williamson	Stream Water	WIC-2	1/29/2002	735	7.95	18.5	2.36
Williamson	Stream Water	WIC-3	1/29/2002	677	8.09	21.2	2.51
Williamson	Stream Water	WIC-4	1/29/2002	708	7.93	19.6	1.77
Williamson	Stream Water	WIC-5	1/29/2002	647			1.84
Williamson	Stream Water	WIC-5	1/30/2002	660	8.1	19.8	3.29
Williamson	Stream Water	WIC-6	1/30/2002	747	7.88	19.1	1.78
Williamson	Stream Water	WIC-7	1/30/2002	735	7.83	19.6	1.86
Williamson	Stream Water	WIC-8	1/30/2002	796	7.75	19.5	2.86
Slaughter	Stream Water	SLC-1	7/22/2002	1097	7.77	28.2	4.29
Slaughter	Stream Water	SLC-2	7/22/2002	670	7.9	30.3	4.65
Slaughter	Stream Water	SLC-3	7/22/2002	941	8.05	27.3	1.88
Slaughter	Stream Water	SLC-4	7/22/2002	818	7.82	26.4	2.39
Slaughter	Stream Water	SLC-5	7/22/2002	707	8.05	32.1	2.10
Slaughter	Stream Water	SLC-6	7/22/2002	492	7.95	30.6	2.45
Slaughter	Stream Water	SLC-7	7/22/2002	480	7.94	29.7	1.10
Barton	Stream Water	BAC-9	8/13/2002	508	8.24	30.5	3.66
Barton	Stream Water	BAC-10	8/13/2002	520	7.91	30.7	3.63
Barton	Stream Water	BAC-11	8/13/2002	593	7.52	26.5	4.54
Barton	Stream Water	BAC-12	8/28/2002		7.07	21.81	5.70
Barton	Stream Water	BAC-13	8/28/2002				3.73
Bull	Rural Tributary	BUC-1	8/15/2002	950	7.49	24.2	3.37
Bull	Rural Tributary	BUC-2	8/14/2002	564	8	29.2	4.22
Bull	Rural Tributary	BUC-2	8/15/2002	564	7.91	28.1	4.09

Table 10 (cont.)

Watershed	Site Classification	Site ID	Collection Date	Conductivity (uS/cm)	pH	Water temperature (deg. C)	Charge Balance (% error)
Bull	Urban Tributary	BUC-3	8/15/2002	1020	7.85	28.5	2.67
Bull	Urban Tributary	BUC-4	8/14/2002	594	8.01	30.9	3.47
West Bull	Rural Tributary	BUC-5	8/14/2002	545	7.96	28	3.76
West Bull	Rural Tributary	BUC-6	8/15/2002	612	7.66	26.6	3.36
Bull	Urban Tributary	BUC-8	8/14/2002	429	8.35	33.5	-0.91
West Bull	Rural Spring	BUC-7	2/22/2006		7.54	16.3	-3.20
West Bull	Rural Spring	BUC-7	4/26/2006		7.78	20.1	-2.14
West Bull	Rural Spring	BUC-7	6/21/2006		7.8	24.2	-1.11
West Bull	Rural Spring	BUC-7	8/19/2006		7.4	21.2	3.21
West Bull	Rural Spring	BUC-7	9/19/2006		7.33	21.9	1.22
West Bull	Rural Spring	BUC-7	10/13/2006		7.74	17.8	3.04
West Bull	Rural Spring	BUC-7	11/3/2006		7.36	11.6	-7.49
West Bull	Rural Spring	BUC-7	12/1/2006		7.37	9.7	4.33
West Bull	Rural Spring	BUC-7	1/12/2007		7.67	18.2	4.33
West Bull	Rural Spring	BUC-7	2/2/2007		7.73	7	9.69
West Bull	Rural Spring	BUC-7	3/1/2007		8.01	18	4.87
Onion	Stream Water	OC-6	4/11/2001	527	8.11	21.9	1.89
Onion	Stream Water	OC-6	3/14/2002	550	8.13	16.9	0.80
Onion	Stream Water	OC-6	3/17/2002	550	8.07	17.7	1.95
Onion	Stream Water	OC-6	12/17/2019	600.7	6.97	11.6	0.19
Onion	Stream Water	OC-7	4/11/2001	524	8.13	22.1	1.87
Onion	Stream Water	OC-8	3/14/2002	526	8.19	18.1	1.22
Onion	Stream Water	OC-9	4/6/2001	514	8.22		0.91
Waller	Stream Water	WAC-6	8/11/2013				7.69
Waller	Stream Water	WAC-6	9/24/2013				4.94

Table 10 (cont.)

Watershed	Site Classification	Site ID	Collection Date	Conductivity (uS/cm)	pH	Water temperature (deg. C)	Charge Balance (% error)
Waller	Stream Water	WAC-6	10/22/2013				8.44
Waller	Stream Water	WAC-6	11/21/2013				2.53
Barton	Stream Water	BAC-7	8/12/2002	525	8.02	30	3.25
Barton	Stream Water	BAC-7	8/13/2002	527	8.03	29.6	3.64
Barton	Stream Water	BAC-5	8/12/2002	596	7.93	28.6	3.60
Barton	Stream Water	BAC-2	8/12/2002	578	7.88	29.9	2.97
Barton	Stream Water	BAC-8	8/13/2002	522	8.08	30.4	3.73
Waller	Pipe Outfall	WAC-5a-20	12/19/2019				-3.74
Waller	Stream Water	WAC-5b-20	12/19/2019	835.4	7.75	10	0.28
Onion	Stream Water	OC-2	12/17/2019	463.8	7.25	11.5	4.30
Onion	Stream Water	OC-5	12/17/2019	774.3	6.43	12.1	2.33

Table 10 (cont.)

Site ID	**Collection Date**	**Sr (ppm)**	**Ca (ppm)**	**Mg (ppm)**	**Na (ppm)**	**K (ppm)**	Lab
WAC-7	10/4/2001	0.4	107.8	12.2	61.8	7.3	ICP-Q-MS (UT DGS)
WAC-7	9/3/2018	0.3	68.5	11.3	37.7	8.4	ICP-Q-MS (UT DGS)
WAC-7	9/9/2018	0.0	14.3	0.9	2.8	1.7	ICP-Q-MS (UT DGS)
WAC-7	10/12/2018	0.3	67.6	9.3	27.3	5.5	ICP-Q-MS (UT DGS)
WAC-7	12/19/2019	0.4	99.0	9.3	40.6	5.3	ICP-Q-MS (UT DGS)
WAC-7	7/31/2018	0.3	88.2	15.3	240.8	11.2	ICP-Q-MS (UT DGS)
WAC-5b-20	7/11/2018	0.2	75.8	7.4	23.0	5.7	ICP-Q-MS (UT DGS)
WAC-5b-20	9/3/2018	0.3	120.9	18.2	32.8	16.9	ICP-Q-MS (UT DGS)
WAC-5	11/29/2018	0.5	137.7	7.4	50.3	3.6	ICP-Q-MS (UT DGS)
WAC-2	8/16/2001	0.4	115.0	9.8	57.9	5.5	ICP-Q-MS (UT DGS)
WAC-2	10/3/2001	0.5	136.2	7.3	58.8	2.8	ICP-Q-MS (UT DGS)
WAC-1	10/3/2001	0.7	151.5	9.8	80.1	2.4	ICP-Q-MS (UT DGS)
CF	8/11/2013	0.3	74.6	16.3	209.1	8.9	ICP-Q-MS (UT DGS)
CF	9/24/2013	0.3	84.1	12.6	111.9	7.7	ICP-Q-MS (UT DGS)
CF	10/22/2013	0.2	66.9	6.9	29.3	4.1	ICP-Q-MS (UT DGS)
CF	11/21/2013	0.6	145.2	11.0	72.2	5.5	ICP-Q-MS (UT DGS)
P104	9/24/2013	0.3	46.6	15.7	30.5	5.7	ICP-Q-MS (UT DGS)
CLASPRING	10/12/2018	0.5	128.3	13.0	290.8	10.6	ICP-Q-MS (UT DGS)
WAC-3-20	7/11/2018	0.2	74.7	3.9	17.6	2.7	ICP-Q-MS (UT DGS)
WAC-3-20	7/31/2018	0.4	73.0	6.1	44.6	2.9	ICP-Q-MS (UT DGS)
WAC-3-20	9/3/2018	0.4	76.5	6.3	42.3	2.3	ICP-Q-MS (UT DGS)
WAC-3-20	9/9/2018	0.1	39.8	2.2	8.3	3.0	ICP-Q-MS (UT DGS)
WAC-3-20	10/12/2018	0.3	85.5	4.2	21.7	3.2	ICP-Q-MS (UT DGS)
WAC-3-20	12/19/2019	0.5	148.7	6.4	39.7	2.6	ICP-Q-MS (UT DGS)
WAC-3-20	11/29/2018	0.5	151.1	6.5	40.2	3.0	ICP-Q-MS (UT DGS)

Table 10 (cont.)

Site ID	Collection Date	Sr (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	Lab
DSIM	7/11/2018	0.2	50.1	3.7	9.1	2.8	ICP-Q-MS (UT DGS)
DSIM	9/9/2018	0.1	21.7	2.8	4.4	2.5	ICP-Q-MS (UT DGS)
WAC-5b-20	10/12/2018	0.3	94.6	8.0	30.9	5.7	ICP-Q-MS (UT DGS)
WAC-5b-20	12/5/2018	0.4	122.2	9.5	46.4	5.7	ICP-Q-MS (UT DGS)
WAC-1-20	7/11/2018	0.2	59.4	3.9	10.6	2.8	ICP-Q-MS (UT DGS)
WAC-1-20	7/31/2018	0.4	69.4	15.3	31.8	4.7	ICP-Q-MS (UT DGS)
WAC-1-20	9/9/2018	0.1	26.5	1.2	3.8	1.9	ICP-Q-MS (UT DGS)
WAC-1-20	12/19/2019	0.6	127.1	5.5	28.7	2.1	ICP-Q-MS (UT DGS)
EASTWOODS	9/9/2018	0.1	22.7	1.3	3.7	3.0	ICP-Q-MS (UT DGS)
EASTWOODS	7/11/2018	0.2	66.7	4.0	15.9	3.1	ICP-Q-MS (UT DGS)
EC	8/11/2013	0.3	71.0	12.6	46.6	6.9	ICP-Q-MS (UT DGS)
EC	9/24/2013	0.3	76.0	11.9	45.7	7.2	ICP-Q-MS (UT DGS)
EC	10/22/2013	0.2	62.9	6.4	26.9	4.1	ICP-Q-MS (UT DGS)
EC	11/21/2013	0.6	133.7	12.5	76.4	6.7	ICP-Q-MS (UT DGS)
WAC-3	10/3/2001	0.5	115.1	7.4	70.6	3.0	ICP-Q-MS (UT DGS)
HD	8/11/2013	0.3	73.3	14.6	39.3	6.3	ICP-Q-MS (UT DGS)
HD	9/24/2013	0.3	86.0	8.9	42.2	6.6	ICP-Q-MS (UT DGS)
HD	10/22/2013	0.3	62.8	8.7	35.2	4.0	ICP-Q-MS (UT DGS)
HD	11/21/2013	0.6	126.9	11.9	73.8	5.0	ICP-Q-MS (UT DGS)
HH	8/11/2013	0.6	105.8	10.7	83.9	4.9	ICP-Q-MS (UT DGS)
HH	9/24/2013	0.5	93.5	10.4	65.4	4.2	ICP-Q-MS (UT DGS)
HH	10/22/2013	0.5	100.5	9.0	59.5	3.8	ICP-Q-MS (UT DGS)
HH	11/21/2013	0.7	140.9	11.2	81.8	5.2	ICP-Q-MS (UT DGS)
WAC-4	10/2/2001	0.4	95.1	9.1	71.5	5.1	ICP-Q-MS (UT DGS)
WAC-1	7/11/2018	0.2	62.6	4.9	13.8	3.0	ICP-Q-MS (UT DGS)

Table 10 (cont.)

Site ID	Collection Date	Sr (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	Lab
WAC-1	9/9/2018	0.1	34.2	1.7	5.6	2.6	ICP-Q-MS (UT DGS)
WAC-1	10/12/2018	0.4	98.4	6.7	25.8	2.8	ICP-Q-MS (UT DGS)
WAC-1	11/29/2018	0.8	165.2	8.7	45.2	2.5	ICP-Q-MS (UT DGS)
WAC-1	6/27/2019	0.5	118.0	6.3	32.7	2.2	ICP-Q-MS (UT DGS)
WAC-1	12/19/2019	0.7	143.9	6.6	40.2	1.6	ICP-Q-MS (UT DGS)
WAC-2	7/11/2018	0.2	65.0	3.7	13.7	2.7	ICP-Q-MS (UT DGS)
P104	8/11/2013	0.3	50.2	16.6	30.8	6.3	ICP-Q-MS (UT DGS)
USIM	7/11/2018	0.2	63.1	4.5	10.8	2.9	ICP-Q-MS (UT DGS)
USRS	7/11/2018	0.3	83.2	4.2	14.2	2.6	ICP-Q-MS (UT DGS)
WAC-10	7/9/2019	0.1	37.0	3.1	10.7	2.9	ICP-Q-MS (UT DGS)
WD	8/11/2013	0.3	97.0	9.7	62.4	4.8	ICP-Q-MS (UT DGS)
AE	7/24/2012	3.5	90.4	22.9	19.3	2.7	ICP-Q-MS (UT DGS)
P105	10/12/2018	0.2	21.4	9.7	19.7	6.7	ICP-Q-MS (UT DGS)
AE	7/27/2012	3.8	110.9	24.5	19.2	2.8	ICP-Q-MS (UT DGS)
AN	7/24/2012	2.0	97.3	20.9	74.1	4.0	ICP-Q-MS (UT DGS)
AN	7/27/2012	1.9	88.0	23.5	70.2	4.1	ICP-Q-MS (UT DGS)
AS	7/24/2012	2.5	94.1	23.0	27.3	1.3	ICP-Q-MS (UT DGS)
AS	7/27/2012	2.5	94.2	22.0	27.1	1.3	ICP-Q-MS (UT DGS)
AS	8/10/2012	2.7	103.9	23.9	32.0	1.4	ICP-Q-MS (UT DGS)
AS	9/25/2012	2.6	103.6	26.0	34.8	1.3	ICP-Q-MS (UT DGS)
WD	9/24/2013	0.4	113.6	8.2	59.9	5.4	ICP-Q-MS (UT DGS)
WD	10/22/2013	0.3	92.4	5.3	34.0	3.2	ICP-Q-MS (UT DGS)
WD	11/21/2013	0.6	162.1	8.7	69.9	3.9	ICP-Q-MS (UT DGS)
P105	8/11/2013	0.1	10.8	17.3	26.9	4.9	ICP-Q-MS (UT DGS)
WAC-6	8/16/2001	0.2	46.6	13.1	63.0	6.4	ICP-Q-MS (UT DGS)

Table 10 (cont.)

Site ID	Collection Date	Sr (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	Lab
P105	9/24/2013	0.1	13.0	18.5	29.5	5.3	ICP-Q-MS (UT DGS)
P105	10/22/2013	0.2	14.2	18.0	27.4	5.2	ICP-Q-MS (UT DGS)
WAC-6	9/1/2001	0.3	101.5	7.7	40.3	5.3	ICP-Q-MS (UT DGS)
P27	7/5/2018	0.2	58.6	15.6	24.7	9.6	ICP-Q-MS (UT DGS)
P27	9/3/2018	0.2	45.0	15.1	24.2	9.6	ICP-Q-MS (UT DGS)
P27	10/12/2018	0.2	41.4	13.3	22.6	6.8	ICP-Q-MS (UT DGS)
P27	12/5/2018	0.2	42.6	11.0	22.3	5.9	ICP-Q-MS (UT DGS)
P27	8/11/2013	0.5	102.1	12.5	39.4	8.8	ICP-Q-MS (UT DGS)
P27	9/24/2013	0.5	116.3	15.5	42.4	13.0	ICP-Q-MS (UT DGS)
P27	10/22/2013	0.6	123.4	13.5	46.8	11.8	ICP-Q-MS (UT DGS)
WAC-5a-20	7/5/2018	0.3	96.0	11.5	24.4	11.8	ICP-Q-MS (UT DGS)
WAC-5a-20	7/31/2018	0.4	144.0	22.5	33.5	14.4	ICP-Q-MS (UT DGS)
WAC-5a-20	9/3/2018	0.3	126.7	19.6	32.0	19.1	ICP-Q-MS (UT DGS)
WAC-5a-20	10/12/2018	0.4	107.8	14.6	37.1	11.0	ICP-Q-MS (UT DGS)
WAC-5a-20	12/5/2018	0.3	98.6	12.3	36.1	9.5	ICP-Q-MS (UT DGS)
WAC-5a-20	8/11/2013	0.4	143.1	23.4	44.2	18.7	ICP-Q-MS (UT DGS)
WAC-5a-20	9/24/2013	0.6	185.9	19.7	49.5	14.3	ICP-Q-MS (UT DGS)
WAC-5a-20	10/22/2013	0.5	168.7	15.7	48.3	10.5	ICP-Q-MS (UT DGS)
AS	3/7/2013	3.0	99.1	25.0	32.4	1.1	ICP-Q-MS (UT DGS)
WAC-6	10/2/2001	0.4	122.0	8.8	91.5	4.6	ICP-Q-MS (UT DGS)
WAC-6	10/4/2001	0.4	115.9	8.6	74.1	4.6	ICP-Q-MS (UT DGS)
WAC-6	10/5/2001	0.4	115.2	8.6	77.5	4.4	ICP-Q-MS (UT DGS)
WAC-6	10/6/2001	0.5	119.4	8.6	74.9	4.5	ICP-Q-MS (UT DGS)
WAC-6	4/29/2002	0.5	128.0	8.4	60.0	3.7	ICP-Q-MS (UT DGS)
AS	6/21/2013	2.9	97.1	23.4	30.3	1.3	ICP-Q-MS (UT DGS)

Table 10 (cont.)

Site ID	Collection Date	Sr (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	Lab
WAC-6	6/16/2002	0.4	98.6	8.4	52.4	3.8	ICP-Q-MS (UT DGS)
WAC-6	6/17/2002	0.2	56.6	4.6	22.6	3.4	ICP-Q-MS (UT DGS)
WAC-6	6/25/2002	0.4	90.4	8.4	55.1	3.9	ICP-Q-MS (UT DGS)
BW	8/29/2010	4.9	130.0	24.9	33.4	1.8	LCRA
BW	4/12/2011	4.1	130.0	23.4	33.7	1.4	LCRA
CC	7/27/2012	0.8	127.5	26.5	60.0	3.5	ICP-Q-MS (UT DGS)
CC	7/24/2012	0.8	130.0	26.3	59.1	3.4	ICP-Q-MS (UT DGS)
ED/BUC-2	7/24/2012	2.5	97.0	25.7	9.8	1.2	ICP-Q-MS (UT DGS)
ED/BUC-2	7/27/2012	2.6	93.6	24.8	9.5	1.2	ICP-Q-MS (UT DGS)
EM	7/24/2012	1.2	94.9	19.4	7.3	0.9	ICP-Q-MS (UT DGS)
EM	7/27/2012	1.3	98.3	22.7	7.9	0.9	ICP-Q-MS (UT DGS)
EN	7/24/2012	1.2	84.7	19.1	7.6	1.3	ICP-Q-MS (UT DGS)
EN	7/27/2012	1.4	89.8	20.4	8.2	1.3	ICP-Q-MS (UT DGS)
FB	3/7/2013	0.2	149.5	18.6	23.7	2.5	ICP-Q-MS (UT DGS)
FB	6/21/2013	0.2	150.9	17.5	21.6	1.7	ICP-Q-MS (UT DGS)
FE	3/7/2013	0.2	114.6	19.0	23.3	2.4	ICP-Q-MS (UT DGS)
FE	6/21/2013	0.2	94.4	15.6	16.2	2.3	ICP-Q-MS (UT DGS)
FE	7/24/2012	0.2	121.5	18.2	20.8	2.6	ICP-Q-MS (UT DGS)
FE	7/27/2012	0.2	115.7	17.3	20.0	2.5	ICP-Q-MS (UT DGS)
FE	8/10/2012	0.2	113.0	18.3	24.5	2.5	ICP-Q-MS (UT DGS)
FE	8/23/2012	0.2	110.8	17.2	20.1	2.4	ICP-Q-MS (UT DGS)
FE	9/25/2012	0.2	113.7	17.5	21.6	2.5	ICP-Q-MS (UT DGS)
FG	3/7/2013	0.6	81.2	26.1	22.8	2.7	ICP-Q-MS (UT DGS)
FG	6/21/2013	0.5	75.5	21.5	18.4	2.6	ICP-Q-MS (UT DGS)
FK	8/23/2010	0.8	101.0	17.3	8.7	0.6	LCRA

Table 10 (cont.)

Site ID	**Collection Date**	**Sr (ppm)**	**Ca (ppm)**	**Mg (ppm)**	**Na (ppm)**	**K (ppm)**	Lab
FK	4/12/2011	0.8	98.2	16.2	8.8	0.5	LCRA
FN	3/7/2013	0.1	67.5	18.9	29.0	3.1	ICP-Q-MS (UT DGS)
FN	6/21/2013	0.1	75.9	17.0	23.2	3.4	ICP-Q-MS (UT DGS)
FN	7/24/2012	0.2	91.8	19.6	26.0	3.2	ICP-Q-MS (UT DGS)
FN	7/27/2012	0.2	87.0	19.7	26.2	3.1	ICP-Q-MS (UT DGS)
FN	8/10/2012	0.2	80.9	18.8	28.2	3.4	ICP-Q-MS (UT DGS)
FN	8/23/2012	0.2	84.7	18.1	25.9	3.2	ICP-Q-MS (UT DGS)
FN	9/25/2012	0.1	74.3	17.8	26.9	3.3	ICP-Q-MS (UT DGS)
FW	7/24/2012	0.3	125.2	24.3	30.8	3.1	ICP-Q-MS (UT DGS)
FW	7/27/2012	0.3	128.2	24.9	32.4	3.1	ICP-Q-MS (UT DGS)
FY	8/29/2010	0.2	119.0	11.6	11.5	0.9	LCRA
FY	4/15/2011	0.2	105.0	10.7	10.8	1.0	LCRA
LN	8/24/2010	0.4	96.9	15.7	9.1	0.5	LCRA
LN	4/12/2011	0.4	104.0	16.5	10.7	0.6	LCRA
LR	8/28/2010	0.3	104.0	19.9	9.4	0.7	LCRA
LR	4/12/2011	0.2	100.0	19.2	9.7	0.8	LCRA
MV	7/24/2012	0.7	97.5	19.3	28.8	3.4	ICP-Q-MS (UT DGS)
MV	7/27/2012	0.7	98.0	19.6	30.2	3.3	ICP-Q-MS (UT DGS)
MV	8/10/2012	0.8	108.0	20.7	34.1	3.4	ICP-Q-MS (UT DGS)
MV	9/25/2012	0.8	104.0	20.6	32.7	3.2	ICP-Q-MS (UT DGS)
MV	3/7/2013	0.7	82.7	20.0	38.4	2.5	ICP-Q-MS (UT DGS)
MV	6/21/2013	0.7	95.3	19.7	34.1	3.1	ICP-Q-MS (UT DGS)
PC	3/7/2013	0.8	104.8	21.9	37.8	1.4	ICP-Q-MS (UT DGS)
PC	6/21/2013	0.9	109.7	21.6	43.5	1.9	ICP-Q-MS (UT DGS)
PN	3/7/2013	0.7	89.9	16.0	9.0	0.5	ICP-Q-MS (UT DGS)

Table 10 (cont.)

Site ID	**Collection Date**	**Sr (ppm)**	**Ca (ppm)**	**Mg (ppm)**	**Na (ppm)**	**K (ppm)**	Lab
PN	6/21/2013	0.8	94.1	17.0	9.0	0.5	ICP-Q-MS (UT DGS)
SH	8/24/2010	0.2	166.0	23.7	40.9	1.6	LCRA
SH	4/12/2011	0.2	160.0	21.9	40.5	1.3	LCRA
WAC-6	6/27/2002	0.2	43.8	3.5	16.2	3.0	ICP-Q-MS (UT DGS)
TB	8/29/2010	0.4	138.0	26.1	17.8	1.0	LCRA
TB	4/12/2011	0.5	137.0	29.4	18.3	1.0	LCRA
TF	8/24/2010	0.7	105.0	15.8	18.7	0.7	LCRA
TF	4/12/2011	0.7	117.0	16.3	15.3	0.4	LCRA
TL	8/28/2010	0.3	140.0	21.1	23.2	2.7	LCRA
TL	4/22/2011	0.2	122.0	19.4	22.5	4.4	LCRA
TR	7/24/2012	0.8	130.4	21.0	26.8	1.9	ICP-Q-MS (UT DGS)
TR	7/27/2012	1.1	134.8	21.0	25.7	1.8	ICP-Q-MS (UT DGS)
TR	8/10/2012	1.6	110.3	23.4	30.0	1.5	ICP-Q-MS (UT DGS)
TR	9/25/2012	1.8	128.4	23.9	29.2	1.9	ICP-Q-MS (UT DGS)
TS/BUC-1	8/24/2010	0.9	130.0	24.4	50.3	2.6	LCRA
TS/BUC-1	4/12/2011	0.9	146.0	27.9	63.6	2.5	LCRA
TT/BUC-3	8/28/2010	1.7	105.0	21.7	40.2	2.2	LCRA
TW	8/19/2010	0.2	146.0	31.9	30.0	1.8	LCRA
WAC-6	5/10/2013	0.2	59.8	6.1	31.9	6.1	ICP-Q-MS (UT DGS)
TW	4/12/2011	0.2	138.0	32.8	29.8	1.6	LCRA
OC-1	4/15/2001	0.2	67.4	23.3	8.2	0.9	UMN ICPMS
OC-1	3/14/2002	0.2	66.7	22.9	8.5	1.3	ICP-Q-MS (UT DGS)
OC-1	12/17/2019	0.2	66.5	17.8	10.9	1.0	ICP-Q-MS (UT DGS)
OC-11	4/6/2001	0.3	76.3	14.4	9.2	0.7	UMN ICPMS
OC-13	4/6/2001	0.3	73.1	13.9	9.1	0.7	UMN ICPMS

Table 10 (cont.)

Site ID	Collection Date	Sr (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	Lab
OC-14	4/9/2001	0.3	72.7	13.8	9.2	0.7	UMN ICPMS
OC-14	3/14/2002	0.4	64.9	18.1	10.0	1.1	ICP-Q-MS (UT DGS)
OC-15	3/17/2002	0.3	57.3	18.5	10.3	1.1	ICP-Q-MS (UT DGS)
OC-15	7/7/2019	0.3	45.4	15.0	9.8	1.5	ICP-Q-MS (UT DGS)
OC-15	4/11/2001	0.3	49.8	13.7	9.3	0.7	UMN ICPMS
OC-16	3/17/2002	0.2	42.7	18.6	9.4	1.0	ICP-Q-MS (UT DGS)
OC-16	4/9/2001	0.2	42.9	13.6	9.0	0.7	UMN ICPMS
OC-17	4/9/2001	0.2	41.6	13.5	9.0	0.8	UMN ICPMS
OC-18	4/11/2001	0.3	48.4	12.9	11.5	1.3	UMN ICPMS
OC-19	3/17/2002	0.7	88.2	11.6	22.4	2.6	ICP-Q-MS (UT DGS)
OC-19	7/7/2019	0.9	70.1	11.8	14.1	2.2	ICP-Q-MS (UT DGS)
OC-19	12/17/2019	0.7	75.8	9.3	21.8	2.8	ICP-Q-MS (UT DGS)
OC-2	3/14/2002	0.2	64.8	20.1	9.7	1.1	ICP-Q-MS (UT DGS)
OC-21	4/8/2001	0.6	91.9	12.0	21.6	2.3	UMN ICPMS
OC-21	7/2/2019	0.7	68.2	10.9	18.7	2.8	ICP-Q-MS (UT DGS)
OC-21	12/17/2019	0.8	93.3	16.7	35.8	4.1	ICP-Q-MS (UT DGS)
OC-22	3/17/2002	0.7	88.6	13.5	29.0	2.4	ICP-Q-MS (UT DGS)
OC-22	12/17/2019	0.7	86.4	20.8	43.8	4.8	ICP-Q-MS (UT DGS)
OC-23	3/17/2002	0.8	97.6	18.2	30.6	2.6	ICP-Q-MS (UT DGS)
OC-3	4/15/2001	0.1	77.4	14.9	6.4	0.9	UMN ICPMS
OC-4	4/15/2001	0.1	72.0	12.8	6.9	0.7	UMN ICPMS
OC-5	4/15/2001	0.3	75.8	14.9	9.3	0.8	UMN ICPMS
OC-5	3/17/2002	0.4	76.2	17.5	10.1	1.2	ICP-Q-MS (UT DGS)
SHCK29th	7/7/2019	0.3	111.7	7.6	43.3	2.4	ICP-Q-MS (UT DGS)
SHC-3	7/7/2019	0.2	46.9	4.3	10.3	2.1	ICP-Q-MS (UT DGS)

Table 10 (cont.)

Site ID	**Collection Date**	**Sr (ppm)**	**Ca (ppm)**	**Mg (ppm)**	**Na (ppm)**	**K (ppm)**	Lab
SHC-9	7/7/2019	0.3	71.2	5.5	28.7	3.1	ICP-Q-MS (UT DGS)
WIC-8	7/7/2019	0.5	80.9	14.6	54.0	8.7	ICP-Q-MS (UT DGS)
WIC-5	7/7/2019	0.2	57.1	5.7	6.6	2.7	ICP-Q-MS (UT DGS)
WIC-2	7/7/2019	0.3	87.3	25.7	16.1	1.9	ICP-Q-MS (UT DGS)
BAC-1	8/12/2002		83.7	26.0	9.2	1.3	ICP-Q-MS (UT DGS)
BAC-5	7/7/2019	0.3	73.8	19.3	20.7	1.7	ICP-Q-MS (UT DGS)
BRCKGbMP	7/7/2019	0.3	57.7	18.3	20.2	2.0	ICP-Q-MS (UT DGS)
BAC-11	7/7/2019	0.7	88.3	19.6	15.2	1.4	ICP-Q-MS (UT DGS)
BLCKHwy360	7/3/2019	0.7	60.6	16.0	19.3	1.8	ICP-Q-MS (UT DGS)
BUC-4	7/3/2019	0.9	60.7	16.6	20.0	1.8	ICP-Q-MS (UT DGS)
BUC-2	7/3/2019	0.7	69.2	16.6	19.9	1.7	ICP-Q-MS (UT DGS)
WAC-6	6/23/2013	0.2	33.1	17.5	32.8	5.4	ICP-Q-MS (UT DGS)
WAC-6	7/14/2013	0.3	88.7	11.1	52.5	5.5	ICP-Q-MS (UT DGS)
SHC-1	10/31/2001	0.5	94.1	9.1	23.1	4.6	UMN ICPMS
SHC-2	10/31/2001	0.4	88.8	9.9	24.4	6.5	UMN ICPMS
SHC-3	10/31/2001	0.3	70.8	8.8	20.4	3.9	UMN ICPMS
SHC-4	10/31/2001	0.4	115.4	7.9	31.6	3.6	UMN ICPMS
SHC-4	11/2/2001	0.4	128.9	8.2	40.2	3.8	UMN ICPMS
SHC-4	11/6/2001	0.4	123.4	8.4	38.5	3.9	UMN ICPMS
SHC-5	11/2/2001	1.4	137.3	12.7	14.9	7.0	UMN ICPMS
SHC-6	11/2/2001	0.4	91.2	10.7	70.0	5.1	UMN ICPMS
SHC-7	11/6/2001	0.5	117.7	8.0	50.2	4.4	UMN ICPMS
SHC-8	10/31/2001	0.4	135.4	11.5	73.1	5.1	UMN ICPMS
SHC-8	11/6/2001	0.5	94.9	11.1	47.3	4.9	UMN ICPMS
SHC-9	11/6/2001	0.4	104.6	8.3	34.4	4.7	UMN ICPMS

Table 10 (cont.)

Site ID	**Collection Date**	**Sr (ppm)**	**Ca (ppm)**	**Mg (ppm)**	**Na (ppm)**	**K (ppm)**	Lab
SHC-12	11/6/2001	0.4	77.2	16.3	39.6	5.8	UMN ICPMS
WIC-1	1/29/2002	0.3	105.6	32.5	32.4	1.1	ICP-Q-MS (UT DGS)
WIC-2	1/29/2002	0.4	98.1	30.9	17.5	0.9	ICP-Q-MS (UT DGS)
WIC-3	1/29/2002	0.4	84.7	28.7	17.7	1.3	ICP-Q-MS (UT DGS)
WIC-4	1/29/2002	0.2	105.5	9.9	26.0	2.7	ICP-Q-MS (UT DGS)
WIC-5	1/29/2002	0.3	93.6	9.8	22.5	3.0	ICP-Q-MS (UT DGS)
WIC-5	1/30/2002	0.4	95.3	10.0	22.8	3.0	ICP-Q-MS (UT DGS)
WIC-6	1/30/2002	0.5	113.3	8.4	29.2	2.9	ICP-Q-MS (UT DGS)
WIC-7	1/30/2002	0.5	109.2	10.8	25.3	2.1	ICP-Q-MS (UT DGS)
WIC-8	1/30/2002	0.6	115.9	12.6	33.4	2.8	ICP-Q-MS (UT DGS)
SLC-1	7/22/2002	0.7	122.2	38.4	57.3	2.7	ICP-Q-MS (UT DGS)
SLC-2	7/22/2002	0.2	91.6	23.0	18.1	1.1	ICP-Q-MS (UT DGS)
SLC-3	7/22/2002	0.5	121.1	37.2	29.9	2.2	ICP-Q-MS (UT DGS)
SLC-4	7/22/2002	0.3	106.6	27.6	29.7	1.3	ICP-Q-MS (UT DGS)
SLC-5	7/22/2002	0.3	82.4	26.8	28.7	1.4	ICP-Q-MS (UT DGS)
SLC-6	7/22/2002		78.6	6.8	12.8	3.5	ICP-Q-MS (UT DGS)
SLC-7	7/22/2002		77.1	6.0	13.4	3.3	ICP-Q-MS (UT DGS)
BAC-9	8/13/2002	0.3	62.6	19.3	16.0	1.5	ICP-Q-MS (UT DGS)
BAC-10	8/13/2002	0.3	63.0	19.0	15.6	1.6	ICP-Q-MS (UT DGS)
BAC-11	8/13/2002	0.3	81.2	20.6	13.3	1.5	ICP-Q-MS (UT DGS)
BAC-12	8/28/2002	0.9	90.2	20.8	13.0	1.4	ICP-Q-MS (UT DGS)
BAC-13	8/28/2002	0.4	93.1	23.4	10.7	1.2	ICP-Q-MS (UT DGS)
BUC-1	8/15/2002	0.9	120.3	26.5	43.9	2.4	ICP-Q-MS (UT DGS)
BUC-2	8/14/2002	1.0	71.6	19.2	19.3	1.6	ICP-Q-MS (UT DGS)
BUC-2	8/15/2002	1.1	71.3	19.1	19.4	1.6	ICP-Q-MS (UT DGS)

Table 10 (cont.)

Site ID	**Collection Date**	**Sr (ppm)**	**Ca (ppm)**	**Mg (ppm)**	**Na (ppm)**	**K (ppm)**	Lab
BUC-3	8/15/2002	1.9	88.2	21.0	99.7	3.7	ICP-Q-MS (UT DGS)
BUC-4	8/14/2002	1.2	66.4	19.6	25.0	2.1	ICP-Q-MS (UT DGS)
BUC-5	8/14/2002	0.7	73.9	19.2	13.0	1.0	ICP-Q-MS (UT DGS)
BUC-6	8/15/2002	0.9	83.2	21.2	14.4	1.3	ICP-Q-MS (UT DGS)
BUC-8	8/14/2002	0.6	49.1	15.0	15.1	2.8	ICP-Q-MS (UT DGS)
BUC-7	2/22/2006	1.7	152.0	52.0	18.0	3.8	ICP-Q-MS (UT DGS)
BUC-7	4/26/2006	1.4	132.0	44.0	20.0	3.8	ICP-Q-MS (UT DGS)
BUC-7	6/21/2006	1.6	159.0	46.0	19.0	4.0	ICP-Q-MS (UT DGS)
BUC-7	8/19/2006	1.9	202.0	51.0	17.0	6.2	ICP-Q-MS (UT DGS)
BUC-7	9/19/2006	1.8	188.0	50.0	17.0	4.1	ICP-Q-MS (UT DGS)
BUC-7	10/13/2006	1.7	175.0	46.0	17.0	4.1	ICP-Q-MS (UT DGS)
BUC-7	11/3/2006	1.1	119.0	30.0	12.0	2.9	ICP-Q-MS (UT DGS)
BUC-7	12/1/2006	1.7	188.0	46.0	18.0	4.1	ICP-Q-MS (UT DGS)
BUC-7	1/12/2007	1.5	165.0	41.0	18.0	3.7	ICP-Q-MS (UT DGS)
BUC-7	2/2/2007	1.4	134.0	39.0	18.0	2.8	ICP-Q-MS (UT DGS)
BUC-7	3/1/2007	1.6	187.0	44.0	19.0	3.5	ICP-Q-MS (UT DGS)
OC-6	4/11/2001	0.3	81.4	14.8	9.5	0.8	UMN ICPMS
OC-6	3/14/2002	0.4	77.3	16.6	9.6	0.9	ICP-Q-MS (UT DGS)
OC-6	3/17/2002	0.4	77.4	17.4	10.1	1.3	ICP-Q-MS (UT DGS)
OC-6	12/17/2019	0.4	81.8	20.7	13.0	1.8	ICP-Q-MS (UT DGS)
OC-7	4/11/2001	0.3	80.9	14.6	9.3	0.8	UMN ICPMS
OC-8	3/14/2002	0.4	72.7	17.7	9.9	1.1	ICP-Q-MS (UT DGS)
OC-9	4/6/2001	0.3	78.1	14.9	9.1	0.7	UMN ICPMS
WAC-6	8/11/2013	0.2	48.6	12.6	37.4	6.0	ICP-Q-MS (UT DGS)
WAC-6	9/24/2013	0.3	91.7	8.2	48.1	5.1	ICP-Q-MS (UT DGS)

Table 10 (cont.)

Site ID	**Collection Date**	**Sr (ppm)**	**Ca (ppm)**	**Mg (ppm)**	**Na (ppm)**	**K (ppm)**	Lab
WAC-6	10/22/2013	0.2	68.0	5.7	31.1	3.2	ICP-Q-MS (UT DGS)
WAC-6	11/21/2013	0.6	152.2	9.7	70.9	4.5	ICP-Q-MS (UT DGS)
BAC-7	8/12/2002		67.1	19.0	14.2	1.4	ICP-Q-MS (UT DGS)
BAC-7	8/13/2002		68.1	19.2	14.4	1.6	ICP-Q-MS (UT DGS)
BAC-5	8/12/2002		79.8	20.0	17.0	1.6	ICP-Q-MS (UT DGS)
BAC-2	8/12/2002		77.2	20.8	12.6	1.5	ICP-Q-MS (UT DGS)
BAC-8	8/13/2002	0.3	65.7	19.1	16.0	1.6	ICP-Q-MS (UT DGS)
WAC-5a-20	12/19/2019	0.4	102.2	15.8	35.6	10.8	ICP-Q-MS (UT DGS)
WAC-5b-20	12/19/2019	0.4	113.7	10.1	44.3	5.6	ICP-Q-MS (UT DGS)
OC-2	12/17/2019	0.2	50.9	22.5	15.3	2.1	ICP-Q-MS (UT DGS)
OC-5	12/17/2019	1.1	97.0	28.4	16.0	2.4	ICP-Q-MS (UT DGS)

Table 10 (cont.)

Site ID	Collection Date	SO4 (ppm)	Cl (ppm)	HCO3 (ppm)	NO3 (ppm)	F (ppm)	Lab
WAC-7	10/4/2001	79.7	97.1	256.2	2.9	0.4	Dionex ICS (UMN)
WAC-7	9/3/2018	69.4	60.6	195.2	2.4	0.6	IC (UT CAEE)
WAC-7	9/9/2018	1.8	4.8	46.4	0.7	0.1	IC (UT CAEE)
WAC-7	10/12/2018	41.9	46.1	216.8	4.1	0.5	IC (UT CAEE)
WAC-7	12/19/2019	66.3	65.4	272.1			IC (UT CAEE)
WAC-7	7/31/2018	60.1	457.9		8.1	0.7	IC (UT CAEE)
WAC-5b-20	7/11/2018	63.6	36.2	231.9	24.3	0.4	IC (UT CAEE)
WAC-5b-20	9/3/2018	137.2	59.5	252.0	27.8	0.8	IC (UT CAEE)
WAC-5	11/29/2018	89.1	87.1	357.3	7.7	0.4	IC (UT CAEE)
WAC-2	8/16/2001	54.4	91.3	280.6	0.3	0.3	Dionex ICS (UMN)
WAC-2	10/3/2001	67.4	92.2	306.0	1.3	0.3	Dionex ICS (UMN)
WAC-1	10/3/2001	72.6	161.2	305.0	0.9	0.5	Dionex ICS (UMN)
CF	8/11/2013	47.8	389.0	130.0	8.3	0.7	Dionex ICS (UMN)
CF	9/24/2013	58.0	199.0	200.9	13.2	0.6	Dionex ICS (UMN)
CF	10/22/2013	38.3	36.4	156.4	7.0	0.3	Dionex ICS (UMN)
CF	11/21/2013	105.0	124.0	312.9	9.8	0.5	Dionex ICS (UMN)
P104	9/24/2013	34.1	47.2	159.5	0.8	0.6	Dionex ICS (UMN)
CLASPRING	10/12/2018	36.6	559.8	235.6	13.5	0.5	IC (UT CAEE)
WAC-3-20	7/11/2018	35.4	29.4	203.5	7.6	0.2	IC (UT CAEE)
WAC-3-20	7/31/2018	68.9	79.4	158.0	3.4	0.3	IC (UT CAEE)
WAC-3-20	9/3/2018	55.0	76.7	172.7	0.2	0.3	IC (UT CAEE)
WAC-3-20	9/9/2018	13.5	12.1	134.3	8.3	0.4	IC (UT CAEE)
WAC-3-20	10/12/2018	14.1	36.7	196.4	8.3	0.2	IC (UT CAEE)
WAC-3-20	12/19/2019	68.3	73.5	389.0			IC (UT CAEE)
WAC-3-20	11/29/2018	76.5	75.9	384.8	10.8	0.4	IC (UT CAEE)

Table 10 (cont.)

Site ID	Collection Date	SO4 (ppm)	Cl (ppm)	HCO3 (ppm)	NO3 (ppm)	F (ppm)	Lab
DSIM	7/11/2018	17.8	13.1	156.8	2.1	0.3	IC (UT CAEE)
DSIM	9/9/2018	7.7	6.3	65.8	8.3	0.4	IC (UT CAEE)
WAC-5b-20	10/12/2018	64.5	50.6	240.3	13.1	0.5	IC (UT CAEE)
WAC-5b-20	12/5/2018	84.2	71.3	313.4	12.7	0.6	IC (UT CAEE)
WAC-1-20	7/11/2018	17.7	14.1	186.7	1.8	0.4	IC (UT CAEE)
WAC-1-20	7/31/2018	40.1	54.7	237.9	3.6	1.0	IC (UT CAEE)
WAC-1-20	9/9/2018	4.2	4.9	77.6	8.1	0.3	IC (UT CAEE)
WAC-1-20	12/19/2019	54.4	43.4	348.1			IC (UT CAEE)
EASTWOODS	9/9/2018	2.1	6.5	69.5	1.5	0.1	IC (UT CAEE)
EASTWOODS	7/11/2018	31.8	25.0	181.2	5.3	0.3	IC (UT CAEE)
EC	8/11/2013	60.1	69.4	174.9	7.7	0.6	Dionex ICS (UMN)
EC	9/24/2013	58.4	66.7	183.0	10.4	0.5	Dionex ICS (UMN)
EC	10/22/2013	34.6	33.1	148.7	5.7	0.2	Dionex ICS (UMN)
EC	11/21/2013	103.0	132.0	276.9	11.9	0.6	Dionex ICS (UMN)
WAC-3	10/3/2001	71.1	107.0	264.0	1.0	0.3	Dionex ICS (UMN)
HD	8/11/2013	50.9	56.1	179.6	1.9	0.6	Dionex ICS (UMN)
HD	9/24/2013	53.2	44.9	222.0	5.0	0.4	Dionex ICS (UMN)
HD	10/22/2013	42.9	38.9	162.7	3.4	0.3	Dionex ICS (UMN)
HD	11/21/2013	117.0	104.0	290.5	4.1	0.5	Dionex ICS (UMN)
HH	8/11/2013	111.0	101.0	268.6	0.5	0.5	Dionex ICS (UMN)
HH	9/24/2013	79.5	70.8	259.7	1.6	0.5	Dionex ICS (UMN)
HH	10/22/2013	92.2	68.3	237.6	5.1	0.4	Dionex ICS (UMN)
HH	11/21/2013	123.0	106.0	327.9	6.4	0.6	Dionex ICS (UMN)
WAC-4	10/2/2001	72.2	90.1	239.1	0.8	0.4	Dionex ICS (UMN)
WAC-1	7/11/2018	24.0	19.7	191.5	3.2	0.2	IC (UT CAEE)

Table 10 (cont.)

Site ID	**Collection Date**	**SO4 (ppm)**	**Cl (ppm)**	**HCO3 (ppm)**	**NO3 (ppm)**	**F (ppm)**	Lab
WAC-1	9/9/2018	5.4	12.1	98.1	0.1	0.1	IC (UT CAEE)
WAC-1	10/12/2018	16.2	41.5	286.5	3.5	0.3	IC (UT CAEE)
WAC-1	11/29/2018	78.3	73.9	433.8	5.9	0.4	IC (UT CAEE)
WAC-1	6/27/2019	66.7	54.2	309.8	10.5	0.5	IC (UT CAEE)
WAC-1	12/19/2019	68.8	71.0	400.4			IC (UT CAEE)
WAC-2	7/11/2018	35.3	29.5	192.8	4.4	0.2	IC (UT CAEE)
P104	8/11/2013	35.2	47.2	140.5	0.4	0.6	Dionex ICS (UMN)
USIM	7/11/2018	20.4	15.1	198.4	2.5	0.3	IC (UT CAEE)
USRS	7/11/2018	25.7	18.7	253.2	5.6	0.3	IC (UT CAEE)
WAC-10	7/9/2019	17.9	15.1	110.4	8.9	0.4	IC (UT CAEE)
WD	8/11/2013	78.4	94.8	216.8	7.8	0.4	Dionex ICS (UMN)
AE	7/24/2012	85.7	40.6	250.3		0.2	HPLC (UT DGS)
P105	10/12/2018	32.5	36.4	67.8		0.7	IC (UT CAEE)
AE	7/27/2012	89.0	43.3	298.9		0.3	HPLC (UT DGS)
AN	7/24/2012	127.7	93.4	269.6	2.8	0.3	HPLC (UT DGS)
AN	7/27/2012	157.7	94.0	212.3		0.4	HPLC (UT DGS)
AS	7/24/2012	53.7	62.3	286.5	8.3	0.2	HPLC (UT DGS)
AS	7/27/2012	54.8	64.0	280.8	6.7	0.2	HPLC (UT DGS)
AS	8/10/2012	59.6	68.0	283.4	1.6	0.2	HPLC (UT DGS)
AS	9/25/2012	65.7	71.7	293.3	0.8	0.1	HPLC (UT DGS)
WD	9/24/2013	91.7	81.5	252.4	16.7	0.4	Dionex ICS (UMN)
WD	10/22/2013	45.9	48.4	197.5	6.8	0.2	Dionex ICS (UMN)
WD	11/21/2013	105.0	128.0	336.4	8.8	0.4	Dionex ICS (UMN)
P105	8/11/2013	27.4	39.5	63.9	0.4	0.5	Dionex ICS (UMN)
WAC-6	8/16/2001	35.2	87.1	165.4	0.6	0.7	Dionex ICS (UMN)

Table 10 (cont.)

Site ID	Collection Date	SO4 (ppm)	Cl (ppm)	HCO3 (ppm)	NO3 (ppm)	F (ppm)	Lab
P105	9/24/2013	30.4	44.1	70.1	0.8	0.6	Dionex ICS (UMN)
P105	10/22/2013	35.8	40.5	63.2	1.9	0.6	Dionex ICS (UMN)
WAC-6	9/1/2001	58.9	54.1	247.9	3.9	0.3	Dionex ICS (UMN)
P27	7/5/2018	102.9	42.3	84.8	12.9	0.7	IC (UT CAEE)
P27	9/3/2018	72.8	42.1	129.2	6.3	0.7	IC (UT CAEE)
P27	10/12/2018	68.9	40.3	116.5	10.6	0.8	IC (UT CAEE)
P27	12/5/2018	56.6	38.1	114.6	9.9	0.8	IC (UT CAEE)
P27	8/11/2013	103.0	57.8	190.2	35.1	0.5	Dionex ICS (UMN)
P27	9/24/2013	126.0	65.1	212.6	54.4	0.5	Dionex ICS (UMN)
P27	10/22/2013	123.0	66.2	249.9	39.3	0.6	Dionex ICS (UMN)
WAC-5a-20	7/5/2018	127.5	55.9	202.7		0.5	IC (UT CAEE)
WAC-5a-20	7/31/2018	199.0	71.5	242.2	72.8	0.6	IC (UT CAEE)
WAC-5a-20	9/3/2018	147.2	59.2	242.8	41.0	0.7	IC (UT CAEE)
WAC-5a-20	10/12/2018	108.7	66.7	235.5	24.3	0.7	IC (UT CAEE)
WAC-5a-20	12/5/2018	93.8	53.4	285.1	22.4	0.7	IC (UT CAEE)
WAC-5a-20	8/11/2013	155.0	70.7	290.5	55.3	0.6	Dionex ICS (UMN)
WAC-5a-20	9/24/2013	185.0	77.2	317.5	120.0	0.5	Dionex ICS (UMN)
WAC-5a-20	10/22/2013	137.0	70.8	315.2	72.3	0.5	Dionex ICS (UMN)
AS	3/7/2013	58.5	63.2	292.2	5.5	0.1	HPLC (UT DGS)
WAC-6	10/2/2001	80.4	136.6	284.5	1.4	0.4	Dionex ICS (UMN)
WAC-6	10/4/2001	80.4	108.2	270.1	1.1	0.4	Dionex ICS (UMN)
WAC-6	10/5/2001	79.8	105.4	287.9	1.0	0.4	Dionex ICS (UMN)
WAC-6	10/6/2001	81.0	105.5	288.9	1.0	0.4	Dionex ICS (UMN)
WAC-6	4/29/2002	87.8	104.0	306.2	0.8	0.5	Dionex ICS (UMN)
AS	6/21/2013	51.6	60.9	304.1		0.1	HPLC (UT DGS)

Table 10 (cont.)

Site ID	Collection Date	SO4 (ppm)	Cl (ppm)	HCO3 (ppm)	NO3 (ppm)	F (ppm)	Lab
WAC-6	6/16/2002	69.9	86.6	249.9	0.7	0.4	Dionex ICS (UMN)
WAC-6	6/17/2002	32.1	35.1	149.3	0.7	0.3	Dionex ICS (UMN)
WAC-6	6/25/2002	71.0	88.5	185.9	0.6	0.4	Dionex ICS (UMN)
BW	8/29/2010	61.1	64.9	363.6	5.1	0.2	LCRA
BW	4/12/2011	66.9	72.1	359.9	7.7	0.1	LCRA
CC	7/27/2012	106.9	90.8	360.9	6.3	0.2	HPLC (UT DGS)
CC	7/24/2012	103.3	90.7	376.0	6.9	0.2	HPLC (UT DGS)
ED/BUC-2	7/24/2012	32.2	24.2	353.1	2.5	0.2	HPLC (UT DGS)
ED/BUC-2	7/27/2012	31.5	25.6	336.0	3.5	0.2	HPLC (UT DGS)
EM	7/24/2012	19.2	18.4	346.7	2.4	0.2	HPLC (UT DGS)
EM	7/27/2012	19.6	19.2	358.7	1.7	0.2	HPLC (UT DGS)
EN	7/24/2012	24.9	18.2	312.1		0.2	HPLC (UT DGS)
EN	7/27/2012	27.4	18.7	308.4	0.8	0.2	HPLC (UT DGS)
FB	3/7/2013	43.3	38.2	442.9	13.0	0.2	HPLC (UT DGS)
FB	6/21/2013	43.7	36.3	447.5	12.6	0.2	HPLC (UT DGS)
FE	3/7/2013	42.0	42.4	325.5	1.9	0.2	HPLC (UT DGS)
FE	6/21/2013	30.5	27.7	328.2		0.2	HPLC (UT DGS)
FE	7/24/2012	46.7	41.7	358.4	4.5	0.3	HPLC (UT DGS)
FE	7/27/2012	46.0	43.2	343.3	3.9	0.3	HPLC (UT DGS)
FE	8/10/2012	45.3	47.1	320.7	2.4	0.2	HPLC (UT DGS)
FE	8/23/2012	41.9	34.9	334.0	1.1	0.2	HPLC (UT DGS)
FE	9/25/2012	42.5	37.3	335.4	1.3	0.2	HPLC (UT DGS)
FG	3/7/2013	50.8	39.6	285.2		0.2	HPLC (UT DGS)
FG	6/21/2013	26.9	27.7	280.6		0.2	HPLC (UT DGS)
FK	8/23/2010	15.0	16.2	344.0		0.1	LCRA

Table 10 (cont.)

Site ID	Collection Date	SO4 (ppm)	Cl (ppm)	HCO3 (ppm)	NO3 (ppm)	F (ppm)	Lab
FK	4/12/2011	17.9	17.1	320.9		0.1	LCRA
FN	3/7/2013	37.7	47.3	257.5		0.5	HPLC (UT DGS)
FN	6/21/2013	28.9	38.5	263.9		0.4	HPLC (UT DGS)
FN	7/24/2012	44.2	54.0	295.2	4.0	0.4	HPLC (UT DGS)
FN	7/27/2012	42.0	52.2	277.2	2.2	0.5	HPLC (UT DGS)
FN	8/10/2012	36.8	47.2	281.2	0.8	0.4	HPLC (UT DGS)
FN	8/23/2012	32.7	42.2	274.0	1.1	0.4	HPLC (UT DGS)
FN	9/25/2012	32.3	43.2	244.6		0.4	HPLC (UT DGS)
FW	7/24/2012	59.2	62.2	376.0	9.7	0.3	HPLC (UT DGS)
FW	7/27/2012	61.8	68.0	384.1	5.5	0.3	HPLC (UT DGS)
FY	8/29/2010	17.0	19.3	353.8	7.5	0.1	LCRA
FY	4/15/2011	18.0	22.5	324.5	6.6	0.1	LCRA
LN	8/24/2010	16.6	17.0	339.2		0.1	LCRA
LN	4/12/2011	20.7	19.6	339.2		0.1	LCRA
LR	8/28/2010	15.0	16.4	356.2	0.8	0.1	LCRA
LR	4/12/2011	17.4	18.8	352.6	1.8	0.1	LCRA
MV	7/24/2012	42.9	47.7	311.1	5.8	0.2	HPLC (UT DGS)
MV	7/27/2012	44.7	52.3	315.5	2.8	0.2	HPLC (UT DGS)
MV	8/10/2012	44.8	50.9	354.4		0.2	HPLC (UT DGS)
MV	9/25/2012	42.8	48.0	314.1		0.2	HPLC (UT DGS)
MV	3/7/2013	48.1	57.3	290.8		0.2	HPLC (UT DGS)
MV	6/21/2013	31.7	45.2	342.2		0.2	HPLC (UT DGS)
PC	3/7/2013	58.0	55.5	323.7	0.5	0.1	HPLC (UT DGS)
PC	6/21/2013	70.2	60.0	332.7		0.1	HPLC (UT DGS)
PN	3/7/2013	18.1	16.3	311.7		0.1	HPLC (UT DGS)

Table 10 (cont.)

Site ID	Collection Date	SO4 (ppm)	Cl (ppm)	HCO3 (ppm)	NO3 (ppm)	F (ppm)	Lab
PN	6/21/2013	17.7	16.6	322.4		0.1	HPLC (UT DGS)
SH	8/24/2010	70.8	88.0	407.5	28.7	0.2	LCRA
SH	4/12/2011	71.1	83.1	398.9	28.7	0.1	LCRA
WAC-6	6/27/2002	18.8	24.7	119.6	0.4	0.2	Dionex ICS (UMN)
TB	8/29/2010	27.0	29.6	480.7	11.0	0.1	LCRA
TB	4/12/2011	29.6	34.8	456.3	9.3	0.1	LCRA
TF	8/24/2010	23.1	36.7	347.7	2.0	0.1	LCRA
TF	4/12/2011	20.4	29.1	373.3	1.8	0.1	LCRA
TL	8/28/2010	37.0	36.9	405.0	5.2	0.3	LCRA
TL	4/22/2011	41.8	43.3	344.0	7.0	0.4	LCRA
TR	7/24/2012	54.8	57.1	376.7	16.6	0.2	HPLC (UT DGS)
TR	7/27/2012	57.4	57.9	368.9	12.1	0.2	HPLC (UT DGS)
TR	8/10/2012	59.1	56.8	302.9	0.9	0.1	HPLC (UT DGS)
TR	9/25/2012	55.1	47.8	323.9	3.9	0.1	HPLC (UT DGS)
TS/BUC-1	8/24/2010	78.5	76.1	397.7	1.6	0.1	LCRA
TS/BUC-1	4/12/2011	105.0	91.6	368.4	2.2	0.1	LCRA
TT/BUC-3	8/28/2010	62.3	57.5	298.9	0.3	0.2	LCRA
TW	8/19/2010	59.0	61.0	468.5	12.1	0.3	LCRA
WAC-6	5/10/2013	39.5	34.7	170.5	8.1	0.3	Dionex ICS (UMN)
TW	4/12/2011	54.0	55.6	428.2	7.6	0.2	LCRA
OC-1	4/15/2001	33.6	14.8	272.8	0.1	0.2	Dionex ICS (UMN)
OC-1	3/14/2002	32.4	14.3	264.5	0.1	0.2	Dionex ICS (UMN)
OC-1	12/17/2019	50.6	22.9	239.8			IC (UT CAEE)
OC-11	4/6/2001	32.5	17.5	236.7	0.2	0.2	Dionex ICS (UMN)
OC-13	4/6/2001	32.5	17.5	244.0	0.1	0.2	Dionex ICS (UMN)

Table 10 (cont.)

Site ID	Collection Date	SO4 (ppm)	Cl (ppm)	HCO3 (ppm)	NO3 (ppm)	F (ppm)	Lab
OC-14	4/9/2001	32.7	17.6	236.7	0.2	0.2	Dionex ICS (UMN)
OC-14	3/14/2002	39.6	17.9	223.3		0.2	Dionex ICS (UMN)
OC-15	3/17/2002	40.4	18.2	199.1		0.2	Dionex ICS (UMN)
OC-15	7/7/2019	30.9	16.8	180.0	7.6	0.4	Dionex ICS (UMN)
OC-15	4/11/2001	32.8	17.7	226.9	0.1	0.2	Dionex ICS (UMN)
OC-16	3/17/2002	38.4	16.7	158.4		0.1	Dionex ICS (UMN)
OC-16	4/9/2001	32.5	17.1	203.5	0.2	0.2	Dionex ICS (UMN)
OC-17	4/9/2001	32.2	16.9	201.5	0.3	0.2	Dionex ICS (UMN)
OC-18	4/11/2001	34.1	19.2	215.2	0.2	0.2	Dionex ICS (UMN)
OC-19	3/17/2002	70.9	24.2	244.2	0.4	0.2	Dionex ICS (UMN)
OC-19	7/7/2019	39.0	19.8	237.9	7.7	0.5	Dionex ICS (UMN)
OC-19	12/17/2019	60.1	20.1	252.6			IC (UT CAEE)
OC-2	3/14/2002	34.1	17.1	240.6	0.0	0.2	Dionex ICS (UMN)
OC-21	4/8/2001	55.3	32.7	255.7	0.9	0.2	Dionex ICS (UMN)
OC-21	7/2/2019	41.9	24.1	233.1	8.3	0.5	Dionex ICS (UMN)
OC-21	12/17/2019	65.5	54.3	353.8			IC (UT CAEE)
OC-22	3/17/2002	69.5	39.7	246.2	1.0	0.3	Dionex ICS (UMN)
OC-22	12/17/2019	69.1	65.1	294.5			IC (UT CAEE)
OC-23	3/17/2002	72.4	37.2	291.6	1.9	0.3	Dionex ICS (UMN)
OC-3	4/15/2001	15.6	11.6	277.7	0.1	0.2	Dionex ICS (UMN)
OC-4	4/15/2001	17.6	13.5	251.8	0.1	0.2	Dionex ICS (UMN)
OC-5	4/15/2001	32.7	17.5	255.0	0.1	0.2	Dionex ICS (UMN)
OC-5	3/17/2002	37.7	18.2	250.8	0.1	0.2	Dionex ICS (UMN)
SHCK29th	7/7/2019	67.4	67.0	293.8	10.1	0.5	IC (UT CAEE)
SHC-3	7/7/2019	19.5	18.5	141.7	7.8	0.5	IC (UT CAEE)

Table 10 (cont.)

Site ID	Collection Date	SO4 (ppm)	Cl (ppm)	HCO3 (ppm)	NO3 (ppm)	F (ppm)	Lab
SHC-9	7/7/2019	61.8	45.3	186.1	8.0	0.5	IC (UT CAEE)
WIC-8	7/7/2019	57.0	75.3	237.4	29.0	1.0	IC (UT CAEE)
WIC-5	7/7/2019	6.9	11.3	215.0	7.7	0.4	IC (UT CAEE)
WIC-2	7/7/2019	35.2	26.6	350.4	7.7	0.5	IC (UT CAEE)
BAC-1	8/12/2002	38.6	16.1	312.3		0.3	Dionex ICS (UMN)
BAC-5	7/7/2019	56.5	30.4	280.6	7.7	0.4	IC (UT CAEE)
BRCKGbMP	7/7/2019	49.3	29.8	224.1	7.8	0.4	IC (UT CAEE)
BAC-11	7/7/2019	32.0	26.7	333.1	10.2	0.4	IC (UT CAEE)
BLCKHwy360	7/3/2019	28.4	29.6	237.8	7.8	0.4	IC (UT CAEE)
BUC-4	7/3/2019	31.9	31.4	195.7	8.0	0.4	IC (UT CAEE)
BUC-2	7/3/2019	28.6	31.0	264.5	7.8	0.4	IC (UT CAEE)
WAC-6	6/23/2013	34.4	47.0	118.9	0.0	0.5	Dionex ICS (UMN)
WAC-6	7/14/2013	47.9	81.9	232.8	1.9	0.5	Dionex ICS (UMN)
SHC-1	10/31/2001	103.0	51.6	187.9		0.4	Dionex ICS (UMN)
SHC-2	10/31/2001	131.7	53.8	124.7		0.2	Dionex ICS (UMN)
SHC-3	10/31/2001	83.6	31.2	147.1	1.1	0.5	Dionex ICS (UMN)
SHC-4	10/31/2001	70.0	55.2	299.1	0.0	0.3	Dionex ICS (UMN)
SHC-4	11/2/2001	73.2	59.4	312.8	0.1	0.3	Dionex ICS (UMN)
SHC-4	11/6/2001	75.4	64.8	314.8		0.3	Dionex ICS (UMN)
SHC-5	11/2/2001	207.4	20.4	215.5	0.0	0.3	Dionex ICS (UMN)
SHC-6	11/2/2001	122.4	89.4	198.4	0.5	0.4	Dionex ICS (UMN)
SHC-7	11/6/2001	101.4	77.3	252.3	1.4	0.5	Dionex ICS (UMN)
SHC-8	10/31/2001	124.9	109.6	268.1	2.0	0.3	Dionex ICS (UMN)
SHC-8	11/6/2001	129.2	76.6	171.8	0.6	0.4	Dionex ICS (UMN)
SHC-9	11/6/2001	76.4	44.4	267.4	0.3	0.3	Dionex ICS (UMN)

Table 10 (cont.)

Site ID	**Collection Date**	**SO4 (ppm)**	**Cl (ppm)**	**HCO3 (ppm)**	**NO3 (ppm)**	**F (ppm)**	Lab
SHC-12	11/6/2001	58.6	55.4	239.6	1.2	0.4	Dionex ICS (UMN)
WIC-1	1/29/2002	86.6	44.6	373.1	0.0	0.2	Dionex ICS (UMN)
WIC-2	1/29/2002	52.1	25.8	369.9	0.2	0.2	Dionex ICS (UMN)
WIC-3	1/29/2002	54.8	25.4	317.4	0.4	0.2	Dionex ICS (UMN)
WIC-4	1/29/2002	62.4	46.7	269.4	0.0	0.2	Dionex ICS (UMN)
WIC-5	1/29/2002	58.7	53.6	216.4	1.5	0.2	Dionex ICS (UMN)
WIC-5	1/30/2002	58.8	53.8	212.5	0.7	0.2	Dionex ICS (UMN)
WIC-6	1/30/2002	78.7	49.8	267.4	0.2	0.3	Dionex ICS (UMN)
WIC-7	1/30/2002	59.4	45.9	285.5	1.2	0.4	Dionex ICS (UMN)
WIC-8	1/30/2002	73.5	52.1	296.5	2.1	0.4	Dionex ICS (UMN)
SLC-1	7/22/2002	157.3	74.8	335.7		0.2	Dionex ICS (UMN)
SLC-2	7/22/2002	56.5	25.8	289.6		0.2	Dionex ICS (UMN)
SLC-3	7/22/2002	122.8	37.5	396.7	0.1	0.2	Dionex ICS (UMN)
SLC-4	7/22/2002	89.3	40.5	337.5	0.0	0.2	Dionex ICS (UMN)
SLC-5	7/22/2002	86.1	39.1	269.9		0.2	Dionex ICS (UMN)
SLC-6	7/22/2002	30.6	18.0	227.7		0.3	Dionex ICS (UMN)
SLC-7	7/22/2002	27.4	19.2	230.8		0.3	Dionex ICS (UMN)
BAC-9	8/13/2002	35.8	27.1	217.9		0.2	Dionex ICS (UMN)
BAC-10	8/13/2002	33.8	26.7	220.2		0.2	Dionex ICS (UMN)
BAC-11	8/13/2002	32.8	23.5	273.5	0.7	0.2	Dionex ICS (UMN)
BAC-12	8/28/2002	27.0	22.0	299.9	0.9	0.2	Dionex ICS (UMN)
BAC-13	8/28/2002	28.7	19.9	321.8	9.8		Dionex ICS (UMN)
BUC-1	8/15/2002	72.0	70.2	369.4	0.3	0.1	Dionex ICS (UMN)
BUC-2	8/14/2002	31.3	32.4	245.0		0.2	Dionex ICS (UMN)
BUC-2	8/15/2002	31.2	32.4	245.2		0.2	Dionex ICS (UMN)

Table 10 (cont.)

Site ID	Collection Date	SO4 (ppm)	Cl (ppm)	HCO3 (ppm)	NO3 (ppm)	F (ppm)	Lab
BUC-3	8/15/2002	123.5	101.3	282.6		0.3	Dionex ICS (UMN)
BUC-4	8/14/2002	41.8	38.6	228.4		0.2	Dionex ICS (UMN)
BUC-5	8/14/2002	25.6	28.2	251.8	0.1	0.2	Dionex ICS (UMN)
BUC-6	8/15/2002	19.6	27.9	303.0		0.2	Dionex ICS (UMN)
BUC-8	8/14/2002	25.6	24.6	200.8		0.2	Dionex ICS (UMN)
BUC-7	2/22/2006	320.0	35.0	360.0	9.0		HPLC (UT DGS)
BUC-7	4/26/2006	220.0	37.0	370.0	4.0		HPLC (UT DGS)
BUC-7	6/21/2006	300.0	36.0	340.0	12.0		HPLC (UT DGS)
BUC-7	8/19/2006	370.0	37.0	330.0	11.0		HPLC (UT DGS)
BUC-7	9/19/2006	340.0	35.0	360.0	8.0		HPLC (UT DGS)
BUC-7	10/13/2006	290.0	34.0	340.0	6.0		HPLC (UT DGS)
BUC-7	11/3/2006	200.0	33.0	330.0	2.0		HPLC (UT DGS)
BUC-7	12/1/2006	270.0	36.0	380.0	7.0		HPLC (UT DGS)
BUC-7	1/12/2007	210.0	37.0	370.0	3.0		HPLC (UT DGS)
BUC-7	2/2/2007	100.0	32.0	360.0	2.0		HPLC (UT DGS)
BUC-7	3/1/2007	280.0	46.0	330.0	8.0		HPLC (UT DGS)
OC-6	4/11/2001	33.9	17.6	262.8	0.2	0.2	Dionex ICS (UMN)
OC-6	3/14/2002	42.1	18.2	256.7		0.2	Dionex ICS (UMN)
OC-6	3/17/2002	42.5	18.3	254.2	0.1	0.2	Dionex ICS (UMN)
OC-6	12/17/2019	57.1	26.2	273.6			IC (UT CAEE)
OC-7	4/11/2001	33.7	17.6	260.6	0.2	0.2	Dionex ICS (UMN)
OC-8	3/14/2002	39.9	17.9	249.7	0.0	0.2	Dionex ICS (UMN)
OC-9	4/6/2001	32.3	17.3	261.6	0.2	0.2	Dionex ICS (UMN)
WAC-6	8/11/2013	42.9	54.3	123.7	1.7	0.5	Dionex ICS (UMN)
WAC-6	9/24/2013	64.9	61.2	217.5	8.0	0.4	Dionex ICS (UMN)

Table 10 (cont.)

Site ID	**Collection Date**	**SO4 (ppm)**	**Cl (ppm)**	**HCO3 (ppm)**	**NO3 (ppm)**	**F (ppm)**	Lab
WAC-6	10/22/2013	35.2	37.7	158.0	5.1	0.2	Dionex ICS (UMN)
WAC-6	11/21/2013	108.0	118.0	324.6	8.1	0.4	Dionex ICS (UMN)
BAC-7	8/12/2002	33.9	24.8	233.3		0.2	Dionex ICS (UMN)
BAC-7	8/13/2002	33.8	24.8	235.5		0.2	Dionex ICS (UMN)
BAC-5	8/12/2002	41.6	29.7	260.6		0.2	Dionex ICS (UMN)
BAC-2	8/12/2002	40.2	23.6	262.5		0.2	Dionex ICS (UMN)
BAC-8	8/13/2002	36.0	27.0	225.2		0.2	Dionex ICS (UMN)
WAC-5a-20	12/19/2019	88.1	53.7	324.6	13.8		IC (UT CAEE)
WAC-5b-20	12/19/2019	81.5	71.6	295.2			IC (UT CAEE)
OC-2	12/17/2019	44.1	26.8	185.4			IC (UT CAEE)
OC-5	12/17/2019	86.6	30.1	303.8			IC (UT CAEE)

Table 10 (cont.)

Site ID	Collection Date	87Sr/86Sr	2σ	Avg. Sr Standard Value	Latitude	Longitude	Source
WAC-7	10/4/2001	0.708728	0.000009	0.710266	30.27496	-97.73542	Christian et al. (2011)
WAC-7	9/3/2018	0.708721	0.000005	0.710261	30.27496	-97.73542	This study
WAC-7	9/9/2018	0.708862	0.000006	0.710261	30.27496	-97.73542	This study
WAC-7	10/12/2018	0.708707	0.000005	0.710256	30.27496	-97.73542	This study
WAC-7	12/19/2019				30.27496	-97.73542	This study
WAC-7	7/31/2018	0.708677	0.000006	0.710252	30.27496	-97.73542	This study
WAC-5b-20	7/11/2018				30.28579	-97.73384	This study
WAC-5b-20	9/3/2018	0.708937	0.000006	0.710261	30.28579	-97.73384	This study
WAC-5	11/29/2018	0.708900	0.000005	0.710256	30.28674	-97.73408	This study
WAC-2	8/16/2001	0.708777	0.000007	0.710266	30.30064	-97.72421	Christian et al. (2011)
WAC-2	10/3/2001	0.708757	0.000008	0.710266	30.30064	-97.72421	Christian et al. (2011)
WAC-1	10/3/2001	0.708573	0.000008	0.710266	30.30719	-97.72671	Christian et al. (2011)
CF	8/11/2013				30.28040	-97.73504	Heitmann
CF	9/24/2013				30.28040	-97.73504	Heitmann
CF	10/22/2013				30.28040	-97.73504	Heitmann
CF	11/21/2013				30.28040	-97.73504	Heitmann
P104	9/24/2013				NA	NA	Heitmann
CLASPRING	10/12/2018				30.28465	-97.73498	This study
WAC-3-20	7/11/2018				30.29692	-97.72519	This study
WAC-3-20	7/31/2018	0.708765	0.000006	0.710252	30.29692	-97.72519	This study
WAC-3-20	9/3/2018	0.708773	0.000005	0.710261	30.29692	-97.72519	This study
WAC-3-20	9/9/2018	0.708641	0.000006	0.710261	30.29692	-97.72519	This study
WAC-3-20	10/12/2018	0.708652	0.000005	0.710256	30.29692	-97.72519	This study
WAC-3-20	12/19/2019				30.29692	-97.72519	This study
WAC-3-20	11/29/2018				30.29692	-97.72519	This study

Table 10 (cont.)

Site ID	Collection Date	87Sr/86Sr	2σ	Avg. Sr Standard Value	Latitude	Longitude	Source
DSIM	7/11/2018				30.31171	-97.72704	This study
DSIM	9/9/2018				30.31171	-97.72704	This study
WAC-5b-20	10/12/2018				30.28579	-97.73384	This study
WAC-5b-20	12/5/2018	0.708976	0.000006	0.710256	30.28579	-97.73384	This study
WAC-1-20	7/11/2018				30.32732	-97.71764	This study
WAC-1-20	7/31/2018	0.708398	0.000005	0.710252	30.32732	-97.71764	This study
WAC-1-20	9/9/2018	0.708065	0.000008	0.710261	30.32732	-97.71764	This study
WAC-1-20	12/19/2019				30.32732	-97.71764	This study
EASTWOODS	9/9/2018				30.29008	-97.73104	This study
EASTWOODS	7/11/2018				30.29008	-97.73104	This study
EC	8/11/2013				NA	NA	Heitmann
EC	9/24/2013				NA	NA	Heitmann
EC	10/22/2013				NA	NA	Heitmann
EC	11/21/2013				NA	NA	Heitmann
WAC-3	10/3/2001	0.708779	0.000006	0.710266	30.29438	-97.72810	Christian et al. (2011)
HD	8/11/2013				NA	NA	Heitmann
HD	9/24/2013				NA	NA	Heitmann
HD	10/22/2013				NA	NA	Heitmann
HD	11/21/2013				NA	NA	Heitmann
HH	8/11/2013				NA	NA	Heitmann
HH	9/24/2013				NA	NA	Heitmann
HH	10/22/2013				NA	NA	Heitmann
HH	11/21/2013				NA	NA	Heitmann
WAC-4	10/2/2001	0.709351	0.000008	0.710266	30.29320	-97.73813	Christian et al. (2011)
WAC-1	7/11/2018				30.30719	-97.72671	This study

Table 10 (cont.)

Site ID	Collection Date	87Sr/86Sr	2σ	Avg. Sr Standard Value	Latitude	Longitude	Source
WAC-1	9/9/2018				30.30719	-97.72671	This study
WAC-1	10/12/2018				30.30719	-97.72671	This study
WAC-1	11/29/2018	0.708553	0.000005	0.710256	30.30719	-97.72671	This study
WAC-1	6/27/2019	0.708540	0.000005	0.710248	30.30719	-97.72671	This study
WAC-1	12/19/2019				30.30719	-97.72671	This study
WAC-2	7/11/2018				30.30064	-97.72421	This study
P104	8/11/2013				NA	NA	Heitmann
USIM	7/11/2018				30.31645	-97.72511	This study
USRS	7/11/2018				30.32769	-97.71784	This study
WAC-10	7/9/2019	0.708743	0.000006	0.710248	30.26207	-97.73927	Loewald
WD	8/11/2013				NA	NA	Heitmann
AE	7/24/2012	0.707931	0.000006	0.710264	30.38267	-97.76894	Senison (2014)
P105	10/12/2018	0.708934	0.000006	0.710256	30.28463	-97.73516	This study
AE	7/27/2012				30.38267	-97.76894	Senison (2014)
AN	7/24/2012	0.708180	0.000006	0.710264	30.38290	-97.76935	Senison (2014)
AN	7/27/2012				30.38290	-97.76935	Senison (2014)
AS	7/24/2012	0.707857	0.000006	0.710264	30.38245	-97.76890	Senison (2014)
AS	7/27/2012				30.38245	-97.76890	Senison (2014)
AS	8/10/2012				30.38245	-97.76890	Senison (2014)
AS	9/25/2012				30.38245	-97.76890	Senison (2014)
WD	9/24/2013				NA	NA	Heitmann
WD	10/22/2013				NA	NA	Heitmann
WD	11/21/2013				NA	NA	Heitmann
P105	8/11/2013				NA	NA	Heitmann
WAC-6	8/16/2001	0.709147	0.000008	0.710266	30.28572	-97.73394	Christian et al. (2011)

Table 10 (cont.)

Site ID	Collection Date	87Sr/86Sr	2σ	Avg. Sr Standard Value	Latitude	Longitude	Source
P105	9/24/2013				NA	NA	Heitmann
P105	10/22/2013				NA	NA	Heitmann
WAC-6	9/1/2001	0.708763	0.000008	0.710266	30.28572	-97.73394	Christian et al. (2011)
P27	7/5/2018				30.28128	-97.73360	This study
P27	9/3/2018	0.708826	0.000005	0.710261	30.28128	-97.73360	This study
P27	10/12/2018				30.28128	-97.73360	This study
P27	12/5/2018				30.28128	-97.73360	This study
P27	8/11/2013				30.28128	-97.73360	Heitmann
P27	9/24/2013				30.28128	-97.73360	Heitmann
P27	10/22/2013				30.28128	-97.73360	Heitmann
WAC-5a-20	7/5/2018				30.28579	-97.73384	This study
WAC-5a-20	7/31/2018	0.708980	0.000006	0.710252	30.28579	-97.73384	This study
WAC-5a-20	9/3/2018	0.708887	0.000007	0.710261	30.28579	-97.73384	This study
WAC-5a-20	10/12/2018	0.709196	0.000005	0.710256	30.28579	-97.73384	This study
WAC-5a-20	12/5/2018				30.28579	-97.73384	This study
WAC-5a-20	8/11/2013				30.28579	-97.73384	Heitmann
WAC-5a-20	9/24/2013				30.28579	-97.73384	Heitmann
WAC-5a-20	10/22/2013				30.28579	-97.73384	Heitmann
AS	3/7/2013				30.38245	-97.76890	Senison (2014)
WAC-6	10/2/2001	0.708851	0.000008	0.710266	30.28572	-97.73394	Christian et al. (2011)
WAC-6	10/4/2001	0.708881	0.000007	0.710266	30.28572	-97.73394	Christian et al. (2011)
WAC-6	10/5/2001	0.708873	0.000008	0.710266	30.28572	-97.73394	Christian et al. (2011)
WAC-6	10/6/2001	0.708877	0.000007	0.710266	30.28572	-97.73394	Christian et al. (2011)
WAC-6	4/29/2002	0.708869	0.000006	0.710266	30.28572	-97.73394	Christian et al. (2011)
AS	6/21/2013				30.38245	-97.76890	Senison (2014)

Table 10 (cont.)

Site ID	**Collection Date**	**87Sr/86Sr**	**2σ**	Avg. Sr Standard Value	**Latitude**	**Longitude**	**Source**
WAC-6	6/16/2002	0.708853	0.000008	0.710266	30.28572	-97.73394	Christian et al. (2011)
WAC-6	6/17/2002	0.708774	0.000010	0.710266	30.28572	-97.73394	Christian et al. (2011)
WAC-6	6/25/2002	0.708934	0.000008	0.710266	30.28572	-97.73394	Christian et al. (2011)
BW	8/29/2010	0.707689	0.000005	0.710264	30.37296	-97.76912	Senison (2014)
BW	4/12/2011	0.707726	0.000006	0.710264	30.37296	-97.76912	Senison (2014)
CC	7/27/2012				30.42657	-97.81410	Senison (2014)
CC	7/24/2012	0.708152	0.000006	0.710264	30.42657	-97.81410	Senison (2014)
ED/BUC-2	7/24/2012	0.707808	0.000005	0.710264	30.40426	-97.79301	Senison (2014)
ED/BUC-2	7/27/2012	0.707813	0.000005	0.710264	30.40426	-97.79301	Senison (2014)
EM	7/24/2012	0.707812	0.000006	0.710264	30.46040	-97.79385	Senison (2014)
EM	7/27/2012	0.707819	0.000005	0.710264	30.46040	-97.79385	Senison (2014)
EN	7/24/2012	0.707814	0.000006	0.710264	30.41618	-97.79561	Senison (2014)
EN	7/27/2012	0.707806	0.000006	0.710264	30.41618	-97.79561	Senison (2014)
FB	3/7/2013	0.708356	0.000006	0.71022	NA	NA	Senison (2014)
FB	6/21/2013	0.708393	0.000006	0.710264	NA	NA	Senison (2014)
FE	3/7/2013	0.708251	0.000006	0.71022	30.40804	-97.75447	Senison (2014)
FE	6/21/2013	0.708270	0.000007	0.710264	30.40804	-97.75447	Senison (2014)
FE	7/24/2012	0.708282	0.000006	0.710264	30.40804	-97.75447	Senison (2014)
FE	7/27/2012	0.708286	0.000006	0.710264	30.40804	-97.75447	Senison (2014)
FE	8/10/2012	0.708285	0.000006	0.710264	30.40804	-97.75447	Senison (2014)
FE	8/23/2012				30.40804	-97.75447	Senison (2014)
FE	9/25/2012	0.708259	0.000006	0.710264	30.40804	-97.75447	Senison (2014)
FG	3/7/2013	0.707864	0.000006	0.71022	30.40636	-97.75383	Senison (2014)
FG	6/21/2013	0.707920	0.000006	0.710264	30.40636	-97.75383	Senison (2014)
FK	8/23/2010	0.707871	0.000006	0.710264	30.41901	-97.81270	Senison (2014)

Table 10 (cont.)

Site ID	Collection Date	87Sr/86Sr	2σ	Avg. Sr Standard Value	Latitude	Longitude	Source
FK	4/12/2011	0.707856	0.000008	0.710264	30.41901	-97.81270	Senison (2014)
FN	3/7/2013	0.708578	0.000006	0.71022	30.41050	-97.75639	Senison (2014)
FN	6/21/2013	0.708524	0.000008	0.710264	30.41050	-97.75639	Senison (2014)
FN	7/24/2012	0.708494	0.000006	0.710264	30.41050	-97.75639	Senison (2014)
FN	7/27/2012	0.708494	0.000006	0.710264	30.41050	-97.75639	Senison (2014)
FN	8/10/2012	0.708518	0.000006	0.710264	30.41050	-97.75639	Senison (2014)
FN	8/23/2012	0.708530	0.000006	0.710264	30.41050	-97.75639	Senison (2014)
FN	9/25/2012	0.708484	0.000006	0.710264	30.41050	-97.75639	Senison (2014)
FW	7/24/2012	0.708192	0.000005	0.710264	30.41082	-97.75726	Senison (2014)
FW	7/27/2012				30.41082	-97.75726	Senison (2014)
FY	8/29/2010	0.708154	0.000005	0.710264	30.42988	-97.83481	Senison (2014)
FY	4/15/2011	0.708175	0.000006	0.710264	30.42988	-97.83481	Senison (2014)
LN	8/24/2010	0.707934	0.000005	0.710264	30.41364	-97.82246	Senison (2014)
LN	4/12/2011	0.707971	0.000008	0.710264	30.41364	-97.82246	Senison (2014)
LR	8/28/2010	0.708045	0.000006	0.710264	30.40464	-97.82644	Senison (2014)
LR	4/12/2011	0.708084	0.000008	0.710264	30.40464	-97.82644	Senison (2014)
MV	7/24/2012	0.708229	0.000006	0.710264	30.42323	-97.79353	Senison (2014)
MV	7/27/2012				30.42323	-97.79353	Senison (2014)
MV	8/10/2012				30.42323	-97.79353	Senison (2014)
MV	9/25/2012				30.42323	-97.79353	Senison (2014)
MV	3/7/2013				30.42323	-97.79353	Senison (2014)
MV	6/21/2013				30.42323	-97.79353	Senison (2014)
PC	3/7/2013				30.42177	-97.80903	Senison (2014)
PC	6/21/2013	0.707852	0.000006	0.710264	30.42177	-97.80903	Senison (2014)
PN	3/7/2013	0.707842	0.000006	0.71022	30.41931	-97.81087	Senison (2014)

Table 10 (cont.)

Site ID	Collection Date	87Sr/86Sr	2σ	Avg. Sr Standard Value	Latitude	Longitude	Source
PN	6/21/2013	0.707965	0.000006	0.710264	30.41931	-97.81087	Senison (2014)
SH	8/24/2010	0.708748	0.000006	0.710264	30.37284	-97.76428	Senison (2014)
SH	4/12/2011	0.708746	0.000005	0.710264	30.37284	-97.76428	Senison (2014)
WAC-6	6/27/2002	0.708757	0.000006	0.710266	30.28572	-97.73394	Christian et al. (2011)
TB	8/29/2010	0.707873	0.000006	0.710264	30.43154	-97.81687	Senison (2014)
TB	4/12/2011	0.707854	0.000010	0.710264	30.43154	-97.81687	Senison (2014)
TF	8/24/2010	0.707778	0.000006	0.710264	30.42695	-97.81846	Senison (2014)
TF	4/12/2011	0.707789	0.000008	0.710264	30.42695	-97.81846	Senison (2014)
TL	8/28/2010	0.708202	0.000006	0.710264	30.40959	-97.75256	Senison (2014)
TL	4/22/2011	0.708223	0.000006	0.710264	30.40959	-97.75256	Senison (2014)
TR	7/24/2012	0.707792	0.000005	0.710264	30.42078	-97.79829	Senison (2014)
TR	7/27/2012				30.42078	-97.79829	Senison (2014)
TR	8/10/2012				30.42078	-97.79829	Senison (2014)
TR	9/25/2012				30.42078	-97.79829	Senison (2014)
TS/BUC-1	8/24/2010	0.707992	0.000006	0.710264	30.42541	-97.81465	Senison (2014)
TS/BUC-1	4/12/2011	0.708047	0.000010	0.710264	30.42541	-97.81465	Senison (2014)
TT/BUC-3	8/28/2010	0.707932	0.000006	0.710264	30.39728	-97.76981	Senison (2014)
TW	8/19/2010	0.708557	0.000006	0.710264	30.43098	-97.78225	Senison (2014)
WAC-6	5/10/2013				30.28572	-97.73394	Heitmann
TW	4/12/2011	0.708578	0.000008	0.710264	30.43098	-97.78225	Senison (2014)
OC-1	4/15/2001	0.707885	0.000006	0.710265	30.17578	-98.18933	Christian et al. (2011)
OC-1	3/14/2002	0.707883	0.000006	0.710268	30.17578	-98.18933	Christian et al. (2011)
OC-1	12/17/2019				30.17578	-98.18933	This study
OC-11	4/6/2001	0.707982	0.000009	0.710259	30.05292	-97.96769	Christian et al. (2011)
OC-13	4/6/2001	0.707976	0.000007	0.710259	30.05072	-97.93764	Christian et al. (2011)

Table 10 (cont.)

Site ID	Collection Date	87Sr/86Sr	2σ	Avg. Sr Standard Value	Latitude	Longitude	Source
OC-14	4/9/2001	0.707978	0.000007	0.710259	30.06183	-97.92628	Christian et al. (2011)
OC-14	3/14/2002	0.707943	0.000006	0.710254	30.06183	-97.92628	Christian et al. (2011)
OC-15	3/17/2002	0.707940	0.000007	0.710254	30.07544	-97.91775	Christian et al. (2011)
OC-15	7/7/2019	0.707950	0.000006	0.710248	30.07544	-97.91775	Loewald
OC-15	4/11/2001	0.707960	0.000007	0.710259	30.07544	-97.91775	Christian et al. (2011)
OC-16	3/17/2002	0.707986	0.000009	0.710254	30.06858	-97.87389	Christian et al. (2011)
OC-16	4/9/2001	0.707969	0.000007	0.710273	30.06858	-97.87389	Christian et al. (2011)
OC-17	4/9/2001	0.707977	0.000008	0.710273	30.07641	-97.86431	Christian et al. (2011)
OC-18	4/11/2001	0.708012	0.000008	0.710273	30.08585	-97.84839	Christian et al. (2011)
OC-19	3/17/2002	0.708103	0.000007	0.710254	30.12592	-97.82183	Christian et al. (2011)
OC-19	7/7/2019	0.707993	0.000006	0.710248	30.12592	-97.82183	Loewald
OC-19	12/17/2019				30.12592	-97.82183	This study
OC-2	3/14/2002	0.707952	0.000006	0.710268	30.18753	-98.11569	Christian et al. (2011)
OC-21	4/8/2001	0.708045	0.000007	0.710273	30.18477	-97.72572	Christian et al. (2011)
OC-21	7/2/2019	0.708057	0.000006	0.710248	30.18477	-97.72572	Loewald
OC-21	12/17/2019				30.18477	-97.72572	This study
OC-22	3/17/2002	0.708092	0.000007	0.710266	30.17792	-97.68922	Christian et al. (2011)
OC-22	12/17/2019				30.17792	-97.68922	This study
OC-23	3/17/2002	0.708031	0.000007	0.710266	30.18933	-97.61850	Christian et al. (2011)
OC-3	4/15/2001	0.708025	0.000007	0.710265	30.13742	-98.15847	Christian et al. (2011)
OC-4	4/15/2001	0.708067	0.000006	0.710265	30.14033	-98.08825	Christian et al. (2011)
OC-5	4/15/2001	0.707951	0.000006	0.710273	30.13119	-98.01619	Christian et al. (2011)
OC-5	3/17/2002	0.707930	0.000007	0.710254	30.13119	-98.01619	Christian et al. (2011)
SHCK29th	7/7/2019	0.709151	0.000006	0.710248	30.29703	-97.74953	Loewald
SHC-3	7/7/2019	0.708242	0.000005	0.710248	30.33432	-97.74969	Loewald

Table 10 (cont.)

Site ID	Collection Date	87Sr/86Sr	2σ	Avg. Sr Standard Value	Latitude	Longitude	Source
SHC-9	7/7/2019	0.708578	0.000006	0.710248	30.27648	-97.75017	Loewald
WIC-8	7/7/2019	0.708243	0.000006	0.710248	30.18946	-97.73308	Loewald
WIC-5	7/7/2019	0.708189	0.000006	0.710248	30.21414	-97.77694	Loewald
WIC-2	7/7/2019	0.708071	0.000006	0.710248	30.24555	-97.88898	Loewald
BAC-1	8/12/2002	0.708078	0.000008	0.710274	30.24443	-98.12257	Christian et al. (2011)
BAC-5	7/7/2019	0.707972	0.000006	0.710248	30.24247	-98.01118	Loewald
BRCKGbMP	7/7/2019	0.707972	0.000006	0.710248	30.24694	-97.81222	Loewald
BAC-11	7/7/2019	0.707964	0.000006	0.710248	30.26368	-97.77298	Loewald
BLCKHwy360	7/3/2019	0.707915	0.000006	0.710248	30.38247	-97.77039	Loewald
BUC-4	7/3/2019	0.707928	0.000005	0.710248	30.36697	-97.78505	Loewald
BUC-2	7/3/2019	0.707920	0.000006	0.710248	30.40603	-97.79352	Loewald
WAC-6	6/23/2013				30.28572	-97.73394	Heitmann
WAC-6	7/14/2013				30.28572	-97.73394	Heitmann
SHC-1	10/31/2001	0.708198	0.000008	0.710272	30.34919	-97.74328	Christian et al. (2011)
SHC-2	10/31/2001	0.708136	0.000008	0.710272	30.34512	-97.74607	Christian et al. (2011)
SHC-3	10/31/2001	0.708598	0.000007	0.710272	30.33432	-97.74969	Christian et al. (2011)
SHC-4	10/31/2001	0.708541	0.000008	0.710272	30.32664	-97.74658	Christian et al. (2011)
SHC-4	11/2/2001	0.708551	0.000008	0.710275	30.32664	-97.74658	Christian et al. (2011)
SHC-4	11/6/2001	0.708569	0.000007	0.710275	30.32664	-97.74658	Christian et al. (2011)
SHC-5	11/2/2001	0.708360	0.000008	0.710272	30.31467	-97.74915	Christian et al. (2011)
SHC-6	11/2/2001	0.708953	0.000007	0.710275	30.30333	-97.74979	Christian et al. (2011)
SHC-7	11/6/2001	0.708412	0.000007	0.710275	30.29228	-97.74807	Christian et al. (2011)
SHC-8	10/31/2001	0.708832	0.000008	0.710275	30.28813	-97.75358	Christian et al. (2011)
SHC-8	11/6/2001	0.708542	0.000008	0.710275	30.28813	-97.75358	Christian et al. (2011)
SHC-9	11/6/2001	0.708462	0.000007	0.710272	30.27648	-97.75017	Christian et al. (2011)

Table 10 (cont.)

Site ID	Collection Date	87Sr/86Sr	2σ	Avg. Sr Standard Value	Latitude	Longitude	Source
SHC-12	11/6/2001	0.708569	0.000008	0.710275	30.26560	-97.75113	Christian et al. (2011)
WIC-1	1/29/2002	0.708089	0.000007	0.710261	30.24230	-97.90682	Christian et al. (2011)
WIC-2	1/29/2002	0.708033	0.000008	0.710261	30.24555	-97.88898	Christian et al. (2011)
WIC-3	1/29/2002	0.708040	0.000006	0.710261	30.23395	-97.85751	Christian et al. (2011)
WIC-4	1/29/2002	0.708683	0.000007	0.710261	30.22120	-97.79353	Christian et al. (2011)
WIC-5	1/29/2002	0.708355	0.000006	0.710261	30.21414	-97.77694	Christian et al. (2011)
WIC-5	1/30/2002	0.708348	0.000007	0.710261	30.21414	-97.77694	Christian et al. (2011)
WIC-6	1/30/2002	0.708197	0.000006	0.710261	30.20159	-97.76122	Christian et al. (2011)
WIC-7	1/30/2002	0.708312	0.000007	0.710261	30.18196	-97.74644	Christian et al. (2011)
WIC-8	1/30/2002	0.708203	0.000007	0.710261	30.18946	-97.73308	Christian et al. (2011)
SLC-1	7/22/2002	0.708028	0.000008	0.710255	30.23540	-97.92573	Christian et al. (2011)
SLC-2	7/22/2002	0.708190	0.000007	0.710274	30.20835	-97.91260	Christian et al. (2011)
SLC-3	7/22/2002	0.707935	0.000007	0.710274	30.22227	-97.90232	Christian et al. (2011)
SLC-4	7/22/2002	0.708098	0.000006	0.710274	30.20953	-97.90370	Christian et al. (2011)
SLC-5	7/22/2002	0.708108	0.000007	0.710274	30.19668	-97.88033	Christian et al. (2011)
SLC-6	7/22/2002	0.708009	0.000007	0.710274	30.15365	-97.79530	Christian et al. (2011)
SLC-7	7/22/2002	0.708073	0.000008	0.710274	30.14875	-97.78472	Christian et al. (2011)
BAC-9	8/13/2002	0.707918	0.000008	0.710274	30.25340	-97.81612	Christian et al. (2011)
BAC-10	8/13/2002	0.707926	0.000007	0.710274	30.25525	-97.79087	Christian et al. (2011)
BAC-11	8/13/2002	0.708085	0.000008	0.710274	30.26368	-97.77298	Christian et al. (2011)
BAC-12	8/28/2002	0.707957	0.000007	0.710274	30.26368	-97.77082	Christian et al. (2011)
BAC-13	8/28/2002				30.26361	-97.77417	Christian et al. (2011)
BUC-1	8/15/2002	0.708004	0.000007	0.710274	30.42570	-97.81457	Christian et al. (2011)
BUC-2	8/14/2002	0.707848	0.000007	0.710257	30.40603	-97.79352	Christian et al. (2011)
BUC-2	8/15/2002	0.707842	0.000008	0.710257	30.40603	-97.79352	Christian et al. (2011)

Table 10 (cont.)

Site ID	Collection Date	87Sr/86Sr	2σ	Avg. Sr Standard Value	Latitude	Longitude	Source
BUC-3	8/15/2002	0.708235	0.000007	0.710255	30.39350	-97.76350	Christian et al. (2011)
BUC-4	8/14/2002	0.707953	0.000008	0.710255	30.36697	-97.78505	Christian et al. (2011)
BUC-5	8/14/2002	0.707784	0.000007	0.710255	30.36942	-97.82085	Christian et al. (2011)
BUC-6	8/15/2002	0.707833	0.000008	0.710255	30.36723	-97.79698	Christian et al. (2011)
BUC-8	8/14/2002	0.708151	0.000008	0.710255	30.35417	-97.78340	Christian et al. (2011)
BUC-7	2/22/2006	0.707990	0.000019	0.710263	30.35642	-97.79322	Christian et al. (2011)
BUC-7	4/26/2006	0.707988	0.000019	0.710263	30.35642	-97.79322	Christian et al. (2011)
BUC-7	6/21/2006				30.35642	-97.79322	Christian et al. (2011)
BUC-7	8/19/2006				30.35642	-97.79322	Christian et al. (2011)
BUC-7	9/19/2006				30.35642	-97.79322	Christian et al. (2011)
BUC-7	10/13/2006	0.707999	0.000019	0.710263	30.35642	-97.79322	Christian et al. (2011)
BUC-7	11/3/2006				30.35642	-97.79322	Christian et al. (2011)
BUC-7	12/1/2006				30.35642	-97.79322	Christian et al. (2011)
BUC-7	1/12/2007				30.35642	-97.79322	Christian et al. (2011)
BUC-7	2/2/2007	0.707986	0.000019	0.710263	30.35642	-97.79322	Christian et al. (2011)
BUC-7	3/1/2007				30.35642	-97.79322	Christian et al. (2011)
OC-6	4/11/2001	0.707976	0.000008	0.710265	30.08489	-98.01333	Christian et al. (2011)
OC-6	3/14/2002	0.707956	0.000007	0.710254	30.08489	-98.01333	Christian et al. (2011)
OC-6	3/17/2002	0.707963	0.000007	0.710266	30.08489	-98.01333	Christian et al. (2011)
OC-6	12/17/2019				30.08489	-98.01333	This study
OC-7	4/11/2001	0.707971	0.000006	0.710265	30.08331	-98.00822	Christian et al. (2011)
OC-8	3/14/2002	0.707940	0.000007	0.710254	30.06053	-97.97728	Christian et al. (2011)
OC-9	4/6/2001	0.707966	0.000008	0.710265	30.06050	-97.97708	Christian et al. (2011)
WAC-6	8/11/2013				30.28572	-97.73394	Heitmann
WAC-6	9/24/2013				30.28572	-97.73394	Heitmann

Table 10 (cont.)

Site ID	Collection Date	87Sr/86Sr	2σ	Avg. Sr Standard Value	Latitude	Longitude	Source
WAC-6	10/22/2013				30.28572	-97.73394	Heitmann
WAC-6	11/21/2013				30.28572	-97.73394	Heitmann
BAC-7	8/12/2002	0.707903	0.000008	0.710274	30.28688	-97.88407	Christian et al. (2011)
BAC-7	8/13/2002	0.707892	0.000007	0.710274	30.28688	-97.88407	Christian et al. (2011)
BAC-5	8/12/2002	0.707882	0.000009	0.710255	30.24247	-98.01118	Christian et al. (2011)
BAC-2	8/12/2002	0.707852	0.000006	0.710255	30.23803	-98.06660	Christian et al. (2011)
BAC-8	8/13/2002	0.707917	0.000007	0.710274	30.27452	-97.84453	Christian et al. (2011)
WAC-5a-20	12/19/2019				30.28579	-97.73384	This study
WAC-5b-20	12/19/2019				30.28579	-97.73384	This study
OC-2	12/17/2019				30.18753	-98.11569	This study
OC-5	12/17/2019				30.13119	-98.01619	This study

Table 11: Bedrock chemical compositions. Chemical concentrations of local to regional carbonates from this study and previously published studies.

				Range of concentrations (ppm) [average]				
Study	**County or Region**	**Geologic Unit**	**# of Analyses**	**Sr**	**Ca**	**Mg**	**Na**	**K**
Unpublished	Travis	Austin Chalk	9	473-651 [547]	327,376-398,284 [355,318]	2,140-2,653 [2,283]	27-90 [56]	14-324 [85]
Demott, 2007	Travis	Glen Rose	3	166-225 [196]	210,000-400,000 [323,333]	1,700-6,500 [3,867]	34-141 [100]	140-600 [313]
Demott, 2007	Travis	Georgetown Fm.	1	201	430,000	2,200	65	140
Demott, 2007	Travis	Walnut Fm.	1	192	270,000	130,000	710	100
Hendrix, 2016*	Lee	Buda Fm./Austin Chalk	1,117	[1035]	27.70%	0.85%	0.32%	0.25%
Peavey, 2017	Brewster	Ernst Member (Austin Chalk-equivalent section; 52.7-84.6 m)	20	336-1,223 [960]	100,205-378,647 [269,125]	NR	NR	1,575-7,888 [3,925]
Musgrove et al., 2010	Regional	Edwards Limestone	12	100-1,000 [140]	300,000-400,000	2,500-50,000 [6,800]	NR	NR
Musgrove et al., 2010	Regional	Edwards Dolomite	N/A	1,000	217,000	132,000	NR	NR
Dravis, 1979	Williamson	Austin Chalk -- Brushy Creek Outcrop	4	730-1100 [966]	NR	1820-2740 [2155]	NR	NR
Dravis, 1979	Bexar	Austin Chalk -- Longhorn Cement Quarry	5	340-940 [475]	NR	1520-2430 [2120]	NR	NR

Table 11 (cont.)

Study	County or Region	Geologic Unit	# of Analyses	Range of concentrations (ppm) [average] Sr	Ca	Mg	Na	K
Dravis, 1979	Bexar	Austin Chalk -- Alamo Cement Quarry	5	280-590 [422]	NR	1550-2100 [1766]	NR	NR
Dravis, 1979	Williamson	Austin Chalk -- Preuse Core	4	570-1150 [788]	NR	1550-2580 [2018]	NR	NR
Dravis, 1979	Bastrop	Austin Chalk -- Standifer Core	2	700-790 [745]	NR	1350-2000 [1675]	NR	NR
Dravis, 1979	Guadalupe	Austin Chalk -- Blumberg Core	4	350-770 [532]	NR	1600-2730 [2225]	NR	NR
Dravis, 1979	Burleson	Austin Chalk -- Varner-Wendler Core	5	1580-2010 [1786]	NR	1510-3010 [2044]	NR	NR
Dravis, 1979	Gonzales	Austin Chalk -- Orts Core	5	900-1290 [1022]	NR	1900-3040 [2334]	NR	NR

*Hierarchical Cluster Analysis results

NR = not reported

REFERENCES

Analysis of Proposed Impervious Cover Entitlements for CodeNEXT Draft 2. (2017). City of Austin Watershed Protection Dept., 6 p.

A Survey of the Subsurface Saline Water of Texas. (1972). Texas Water Development Board Report 157, 1, 113.

Summary of Reported Water Loss Audits by County as of 11/8/2020. (2020). Texas Water Development Board, 11 pp.

Aron, P. G., Poulsen, C. J., Fiorella, R. P., Matheny, A. M., & Veverica, T. J. (2020). An isotopic approach to partition evapotranspiration in a mixed deciduous forest. Ecohydrology, 13(6). https://doi.org/10.1002/eco.2229

Banner, J. L. & Hanson, G. N. (1990). Calculation of simultaneous isotopic and trace-element variations during water-rock interaction with applications to carbonate diagenesis. Geochimica et Cosmochimica Acta 54, 3123-3137

Banner, J. L., & Kaufman, J. (1994). The isotopic record of ocean chemistry and diagenesis preserved in non-luminescent brachiopods from Mississippian carbonate rocks, Illinois and Missouri. Geological Society of America Bulletin, 106, 1074–1082. http://pubs.geoscienceworld.org/gsa/gsabulletin/article-pdf/106/8/1074/3382048/i0016-7606-106-8-1074.pdf

Banner, J.L., Musgrove, M., Capo, R.C. (1994) Tracing groundwater evolution in a limestone aquifer using Sr isotopes: effects of multiple sources of dissolved ions and mineral- solution reactions. Geology 22, 687?690.

Banner, J. L., Wasserburg, G. J., Dobson, P. F., Carpenter, A. B., & Moore, C. H. (1989). Isotopic and trace-element constraints on the origin and evolution of saline groundwaters from central Missouri. Geochimica and Cosmochimica Acta 53, 383-398.

Beal, L., Senison, J., Banner, J., Musgrove, M. L., Yazbek, L., Bendik, N., Herrington, C., & Reyes, D. (2020). Stream and Spring Water Evolution in a Rapidly Urbanizing Watershed, Austin, TX. Water Resources Research, 56(4), 17. https://doi.org/10.1029/2019WR025623

Bendik, N. F., Sissel, B. N., Fields, J. R., O'donnell, L. J., & Sanders, M. S. (2014). Effect of Urbanization on Abundance of Jollyville Plateau Salamanders (Eurycea Tonkawae). Herpetological Conservation and Biology, 9(1), 206–222. http://txsdc.utsa.edu/Data/TPEPP/Projections/Index.aspx

Bjornn, T. C., & Reiser, D. W. (1991). Habitat requirements of salmonids in streams. Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats, 19, 83–138.

Boyd, M. J., Bufill, M. C., & Knee, R. M. (1993). Pervious and impervious runoff in urban catchments. Hydrological Sciences Journal, 38(6), 463–478. https://doi.org/10.1080/02626669309492699

Brune, G., & Duffin, G. (1983). Occurrence availability and quality of ground water in Travis County, Texas. Texas Department of Water Resources Report 276, 219 p.

Buhmann, D., & Dreybrodt, W. (1985). The kinetics of calcite dissolution and precipitation in geologically relevant situations of karst areas. 1. Open system. Chemical Geology, 48(1–4), 189–211. https://doi.org/10.1016/0009-2541(85)90046-4

Burkhalter-Castro, R., Banner, J., Black, B., Beal, L. K., & Holland, J. (2018, December). Can trees record impacts of urban growth on watersheds? In AGU Fall Meeting 2018. AGU.

Christian, L.N., Banner, J.L. & Mack, L.E. (2011). Sr isotopes as tracers of anthropogenic influences on stream water in the Austin, Texas, area, Chemical Geology, 282, 84-97.

Clinton, B.D., & Vose, J.M. (2006). Variation in stream water quality in an urban headwater stream in the southern Appalachians. Water, Air, Soil Pollut.,169, 331–353

DeMott, L.M., Banner, J.L. & Christian, L. (2006). Recent travertine deposits as records of groundwater processes in urbanizing environments, Geological Society of America Annual Meeting Abstract Paper No. 116-2

Dreybrodt, W., Eisenlohr, L., Madry, B., & Ringer, S. (1997). Precipitation kinetics of calcite in the system CaCO3 - H2O - CO2: The conversion to CO2 by the slow process H+ + HCO3- → CO2 + H2O as a rate limiting step. Geochimica et Cosmochimica Acta, 61(18), 3897–3904. https://doi.org/10.1016/s0016-7037(97)00201-9

Dunne, T., & Leopold, L.B. (1978). Water in Environmental Planning. San Francisco: W.H. Freeman and Co.

Fausch, K. D., & Northcote, T. G. (1992). Large Woody Debris and Salmonid Habitat in a SmallCoastal British Columbia Stream. Can. J. Fish. Aquat. Sci., 49, 682–693.

Feyisa, G. L., Dons, K., & Meilby, H. (2014). Efficiency of parks in mitigating urban heat island effect: An example from Addis Ababa. Landscape and Urban Planning, 123, 87–95. https://doi.org/10.1016/j.landurbplan.2013.12.008

Frauendorfer, R., Liemberger, R., & Bank, A.D. (2010). The issues and challenges of reducing non-revenue water. Asian Development Bank, Mandaluyong City.

Gabor, C. R., Davis, D. R., Kim, D. S., Zabierek, K. C., & Bendik, N. F. (2018). Urbanization is associated with elevated corticosterone in Jollyville Plateau salamanders. Ecological Indicators, 85, 229–235. https://doi.org/10.1016/j.ecolind.2017.10.047

Gál, B., Szivák, I., Heino, J., & Schmera, D. (2019). The effect of urbanization on freshwater macroinvertebrates – Knowledge gaps and future research directions. Ecological Indicators, 104, 357–364. https://doi.org/10.1016/j.ecolind.2019.05.012

Garcia-Fresca & Sharp, J.M. (2005). Hydrologic considerations of urban development: urban induced recharge, Rev. Eng. Geol., 16, 123-136.

Geismar, E. (2001). Bull Creek Water Quality Update, 2001. City of Austin, Department of Watershed Protection.

Georgi, N. J., & Zafiriadis, K. (2006). The impact of park trees on microclimate in urban areas. Urban Ecosystems, 9(3), 195–209. https://doi.org/10.1007/s11252-006-8590-9

Girija, T. R., Mahanta, C., & Chandramouli, V. (2007). Water quality assessment of an untreated effluent impacted urban stream: The Bharalu tributary of the Brahmaputra River, India. Environmental Monitoring and Assessment, 130(1–3), 221–236. https://doi.org/10.1007/s10661-006-9391-6

Glick, R.H. (2009). Impacts of impervious cover and other factors on storm-water quality in Austin, Texas. J Hydrol Eng, 14, 316–323.

Gold, A. J., Groffman, P. M., Addy, K., Kellogg, D. Q., Stolt, M., & Rosenblatt, A. E. (2001). Landscape attributes as controls on ground water nitrate removal capacity of riparian zones. Journal of the American Water Resources Association, 37(6), 1457–1464. https://doi.org/10.1111/j.1752-1688.2001.tb03652.x

Granato, G.E., DeSimone, L.A., Barbaro, J.R., & Jeznach, L.C. (2015). Methods for evaluating potential sources of chloride in surface waters and groundwaters of the conterminous United States: U.S. Geological Survey Open-File Report 2015–1080, 89 p., http://dx.doi.org/10.3133/ofr20151080

Gregory, S. V., Swanson, F. J., McKee, W. A., & Cummins, K. W. (1991). An Ecosystem Perspective of Riparian Zones. BioScience, 41(8), 540–551. https://doi.org/10.2307/1311607

Groffman, P. M., Bain, D. J., Band, L. E., Belt, K. T., Brush, G. S., Grove, J. M., Pouyat, R. V., Yesilonis, I. C., & Zipperer, W. C. (2003). Down by the riverside: urban riparian ecology. Frontiers in Ecology and the Environment, 1(6), 315–321. https://doi.org/10.1890/1540-9295(2003)001[0315:DBTRUR]2.0.CO;2

Gunawardena, K. R., Wells, M. J., & Kershaw, T. (2017). Utilising green and bluespace to mitigate urban heat island intensity. Science of the Total Environment, 584–585, 1040–1055. https://doi.org/10.1016/j.scitotenv.2017.01.158

Hardison, E. C., O'Driscoll, M. A., DeLoatch, J. P., Howard, R. J., & Brinson, M. M. (2009). Urban Land Use, Channel Incision, and Water Table Decline Along Coastal

Plain Streams, North Carolina. JAWRA Journal of the American Water Resources Association, 45(4), 1032–1046. https://doi.org/10.1111/j.1752-1688.2009.00345.x

Hovorka, S. D., 1998, Facies and diagenesis of the Austin Chalk and controls on fracture intensity — a case study from North Central Texas: The University of Texas at Austin, Bureau of Economic Geology, Geological Circular 98-2, 47.

IPCC, (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Keller, E. A., & Swanson, F. J. (1979). Effects of large organic material on channel form and fluvial processes. Earth Surface Processes, 4(4), 361–380. https://doi.org/10.1002/esp.3290040406

Kiley, D. K., & Schneider, R. L. (2005). Riparian roots through time, space and disturbance. Plant and Soil, 269(1–2), 259–272. https://doi.org/10.1007/s11104-004-0542-7

Kotlash, A. R., & Chessman, B. C. (1998). Effects of water sample preservation and storage on nitrogen and phosphorus determinations: Implications for the use of automated sampling equipment. Water Research, 32(12), 3731–3737. https://doi.org/10.1016/S0043-1354(98)00145-6

Langmuir, D. (1971). The geochemistry of some carbonate ground waters in central Pennsylvania. Geochimica et Cosmochimica Acta, v. 35, p. 1023-1045.

Larsen, D., Gentry, R. W., & Solomon, D. K. (2003). The geochemistry and mixing of leakage in a semi-confined aquifer at a municipal well field, Memphis, Tennessee, USA. Applied Geochemistry, 18(7), 1043–1063. https://doi.org/10.1016/S0883-2927(02)00204-4

Lassettre, N. S., & Kondolf, G. M. (2012). Large woody debris in urban stream channels: Redefining the problem. River Research and Applications, 28, 1477–1487. https://doi.org/10.1002/rra

Lerner, D. N. (2002). Identifying and quantifying urban recharge: a review. Hydrogeology Journal, 10, 143–152. https://doi.org/10.1007/s10040-001-0177-1

Lerner, D. N. (1986). Leaking Pipes Recharge Ground Water. Ground Water, 24(5), 654–662. https://doi.org/10.1111/j.1745-6584.1986.tb03714.x

Lockmiller, K. A., Wang, K., Fike, D. A., Shaughnessy, A. R., & Hasenmueller, E. A. (2019). Using multiple tracers (F−, B, δ 11 B, and optical brighteners) to distinguish between municipal drinking water and wastewater inputs to urban streams. Science of the Total Environment, 671, 1245–1256. https://doi.org/10.1016/j.scitotenv.2019.03.352

Maher, W., & Woo, L. (1998). Procedures for the storage and digestion of natural waters for the determination of filterable reactive phosphorus, total filterable phosphorus and total phosphorus. Analytica Chimica Acta, 375(1–2), 5–47. https://doi.org/10.1016/S0003-2670(98)00274-8

Mahler, B. J., Musgrove, M., Herrington, C., & Sample, T. L. (2011). Recent (2008-10) concentrations and isotopic compositions of nitrate and concentrations of wastewater compounds in the Barton Springs zone, south-central Texas, and their potential relation to urban development in the contributing zone. In U.S. Geological Survey Scientific Investigations Report 2011-5018.

McGillen, M.R. & Fairchild, I.J. (2005). An experimental study of incongruent dissolution of $CaCO_3$ under analogue glacial conditions, Journal of Glaciology, 51(174), 383–390.

Meyer, J. L., Paul, M. J., & Taulbee, K. W. (2005). Stream ecosystem function in urbanizing landscapes. Journal of the North American Benthological Society, 24(3), 602–612.

Musgrove, M. L., & Banner, J. L. (2004). Controls on the spatial and temporal variability of vadose dripwater geochemistry: Edwards aquifer, central Texas. Geochimica et Cosmochimica Acta, 68(5), 1007–1020. https://doi.org/10.1016/j.gca.2003.08.014

Musgrove, M., Fahlquist, L., Houston, N. A., Lindgren, R. J., & Ging, P. B. (2010). Geochemical evolution processes and water-quality observations based on results of the National Water-Quality Assessment Program in the San Antonio segment of the Edwards Aquifer, Texas, 1996-2006. 108. https://doi.org/10.3133/sir20105129

Musgrove, M., Stern, L. A., & Banner, J. L. (2010). Springwater geochemistry at Honey Creek State Natural Area, central Texas: Implications for surface water and groundwater interaction in a karst aquifer. Journal of Hydrology, 388(1–2), 144–156. https://doi.org/10.1016/j.jhydrol.2010.04.036

Nedeau, E. J., Merritt, R. W., & Kaufman, M. G. (2003). The effect of an industrial effluent on an urban stream benthic community: Water quality vs. habitat quality. Environmental Pollution, 123(1), 1–13. https://doi.org/10.1016/S0269-7491(02)00363-9

Oliveira, S., Andrade, H., & Vaz, T. (2011). The cooling effect of green spaces as a contribution to the mitigation of urban heat: A case study in Lisbon. Building and Environment, 46(11), 2186–2194. https://doi.org/10.1016/j.buildenv.2011.04.034

Osterman, J. W. (1990). Evaluating the Impact of Municipal Water Fluoridation on the Aquatic Environment. American Journal of Public Health, 80(10), 1230–1235.

Panno, S. V., Hackley, K. C., Hwang, H. H., Greenberg, S. E., Krapac, I. G., Landsberger, S., & O'Kelly, D. J. (2006). Characterization and identification of Na-Cl sources in ground water. Ground Water, 44(2), 176–187. https://doi.org/10.1111/j.1745-6584.2005.00127.x

Paul, M. J., & Meyer, J. L. (2001). Streams in the Urban Landscape. Annual Review of Ecology and Systematics, 32(1), 333–365. https://doi.org/10.1146/annurev.ecolsys.32.081501.114040

Pfaff, J. D. (1993). Method 300.0 Determination of Inorganic Anions by Ion Chromatography.

Porras, A., Richter, A., Hiers, S., Clamann, A., Scoggins, M., Herrington, C., Burdick, W., & Sudduth, S. (2016) Reclaimed water irrigation water quality impact assessment, City of Austin Watershed Protection Department SR-16-06, 1-50. http://www.austintexas.gov/watershed_protection/publications/document.cfm?id=263438

Ragab, R., Rosier, P., Dixon, A., Bromley, J., & Cooper, J. D. (2003). Experimental study of water fluxes in a residential area: 2. Road infiltration, runoff and evaporation. Hydrological Processes, 17(12), 2423–2437. https://doi.org/10.1002/hyp.1251

Reynolds, J.H. and Barrett, H.M. (2003). A review of the effects of sewer leakage on groundwater quality. Journ. Chart. Inst. Water & Environ. Mangt., 17(1), 34 – 39.

Rhodes, A. L., Newton, R. M., & Pufall, A. (2001). Influences of Land Use on Water Quality of a Diverse New England Watershed. Environ. Sci. Technol., 35, 3640–3645. https://doi.org/10.1021/es002052u

Schoonover, J. E., Lockaby, B. G., & Pan, S. (2005). Changes in chemical and physical properties of stream water across an urban-rural gradient in western Georgia. Urban Ecosystems, 8(1), 107–124. https://doi.org/10.1007/s11252-005-1422-5

Schueler, T. (2000). The importance of imperviousness: the practice of watershed protection. Center for Watershed Protection, Ellcott City, MD, 7-18.

Scribner, B. E. A., Goolsby, D. A., Thurman, E. M., Meyer, M. T., & Pomes, M. L. (1994). Concentrations of Selected Herbicides, Two Triazine Metabolites, and Nutrients in Storm Runoff From Nine Stream Basins in the Midwestern United States, 1990-92. U.S. Geological Survey Open-File Report 94-396, 144.

Shuster, W. D., Gehring, R., & Gerken, J. (2007). Prospects for enhanced groundwater recharge via infltration of urban storm water runoff: A case study. Journal of Soil and Water Conservation, 62(3), 129–136.

Sinclair, D. J., Banner, J. L., Taylor, F. W., Partin, J., Jenson, J., Mylroie, J., Goddard, E., Quinn, T., Jocson, J., & Miklavič, B. (2012). Magnesium and strontium systematics in tropical speleothems from the Western Pacific. Chemical Geology, 294–295, 1–17. https://doi.org/10.1016/j.chemgeo.2011.10.008

Soil survey of Travis County. (1970). Texas, US Department of Agriculture, Soil Conservation Service.

Solins, J. P., & Cadenasso, M. L. (2020). Urban channel incision and stream flow subsidies have contrasting effects on the water status of riparian trees. Urban Ecosystems, 23(2), 419–430. https://doi.org/10.1007/s11252-020-00926-2

Stowell, J. F. W. (2001). Characterization of Opening Mode Fracture Systems in the Austin Chalk. Gulf Coast Association of Geological Societies Transactions, 51, 313–319. https://doi.org/10.1306/8626cf9b-173b-11d7-8645000102c1865d

Susca, T., Gaffin, S. R., & Dell'Osso, G. R. (2011). Positive effects of vegetation: Urban heat island and green roofs. Environmental Pollution, 159(8–9), 2119–2126. https://doi.org/10.1016/j.envpol.2011.03.007

Townsend, M. A., & Whittemore, D. O. (2005). Identification of nitrate and chloride sources affecting municipal well waters of the city of McPherson, Kansas. Kansas Geological Survey Open File Report 2005-34. www.kgs.ku.edu

U.S. Census Bureau (2010). Department of Commerce Economics and Statistics Administration, 2010 Census of Population General Population Characteristics Texas, Section 1 of 2.

USGCRP (2018). Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 1515 pp. doi: 10.7930/NCA4.2018

Walsh, C. J., Roy, A. H., Feminella, J. W., Cottingham, P. D., Groffman, P. M., & Ii, R. P. M. (2005). The urban stream syndrome: current knowledge and the search for a cure. The North American Benthological Society, 24(3), 706–723.

Wang, B., Liu, D., Liu, S., Zhang, Y., Lu, D., & Wang, L. (2012). Impacts of urbanization on stream habitats and macroinvertebrate communities in the tributaries of Qiangtang River, China. Hydrobiologia, 680(1), 39–51. https://doi.org/10.1007/s10750-011-0899-6

Wang, L., & Kanehl, P. (2003). Influences of Watershed Urbanization and Instream habitat on Macroinvertebrates in Cold Water Streams. Journal of the American Water Resources Association, 39(5), 1181–1196. https://doi.org/10.1111/j.1752-1688.2003.tb03701.x

Wong, C.I., Mahler, B.J., Musgrove, M., & Banner, J.L. 2012. Changes in sources and storage in a karst aquifer during a transition from drought to wet conditions, Journal of Hydrology, 468–469, 159–172.

Wong, C.I., Kromann, J.S., Hunt, B.B., Smith, B.S., and Banner, J.L. 2014. Investigating groundwater flow between Edwards and Trinity Aquifers in Central Texas. Groundwater, 52(4). 624-639.

Young, K. (1977). Guidebook to the Geology of Travis County. The Student Geology Society, The University of Texas. https://repositories.lib.utexas.edu/bitstream/handle/2152/63760/Guidebook to the Geology of Travis County.pdf?sequence=2&isAllowed=y